RULES AND REGULATIONS FOR THE CLASSIFICATION OF SPECIAL SERVICE CRAFT

REGULATIONS

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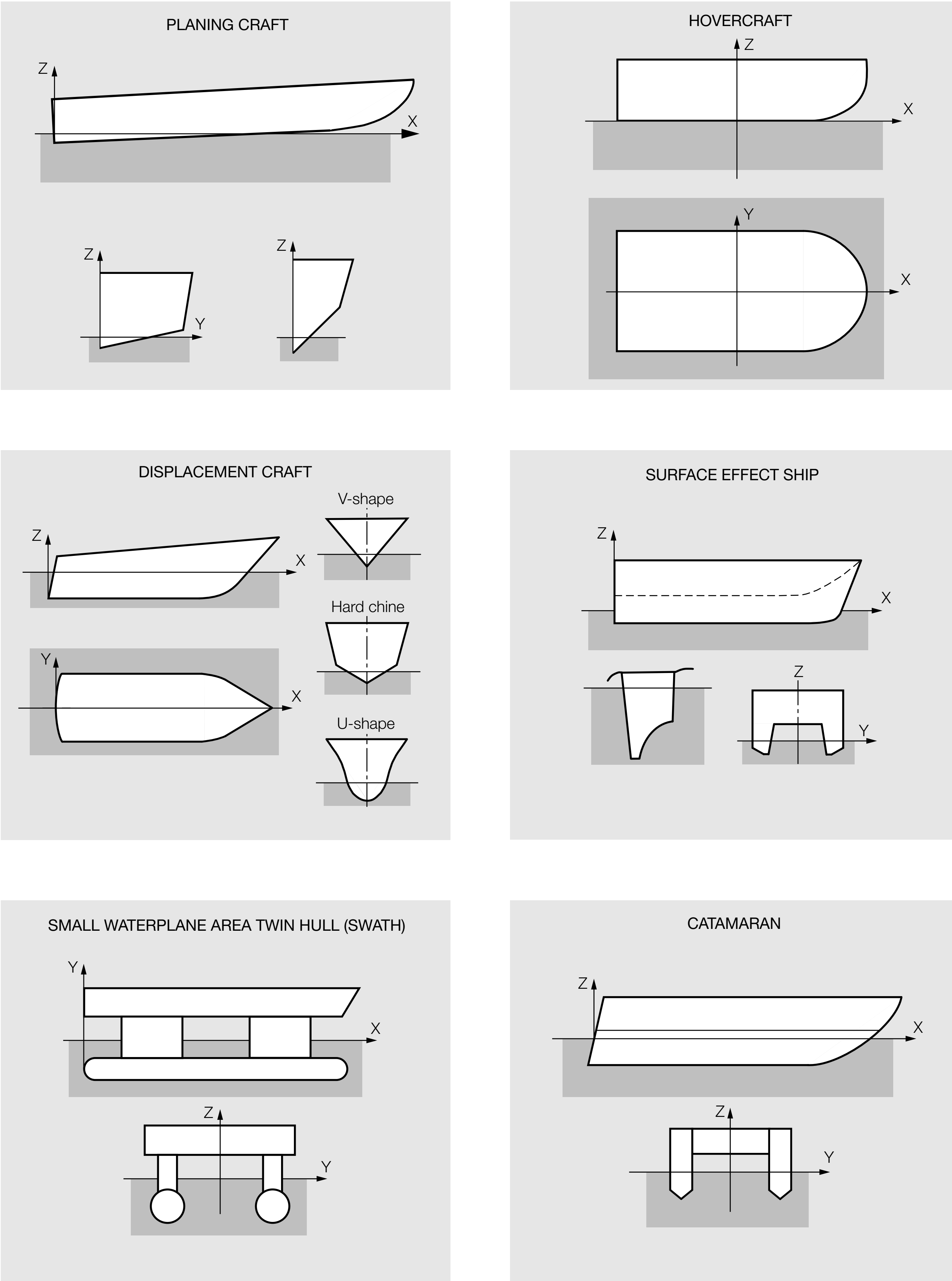
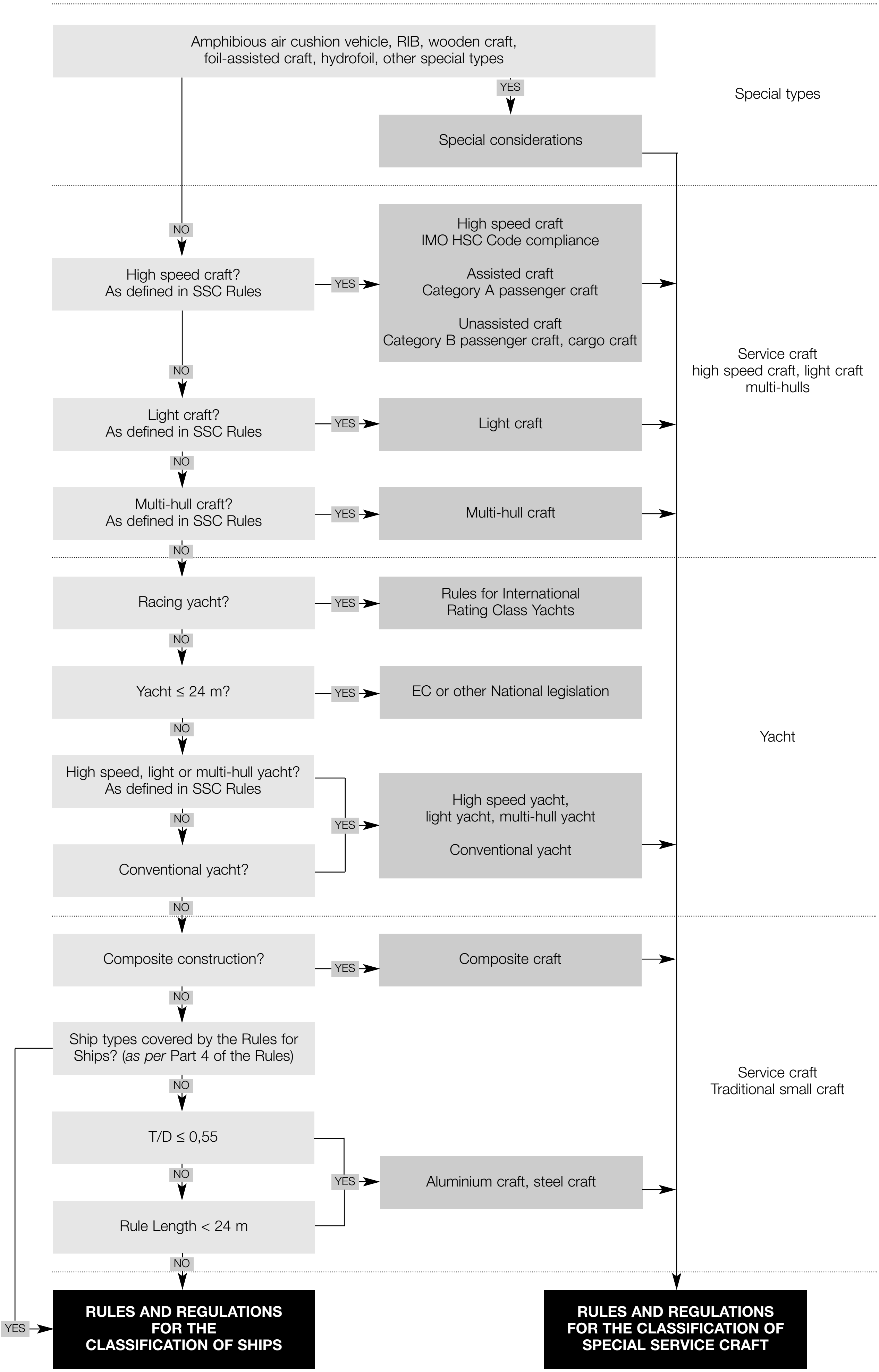
Lloyd's Register

DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES



DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



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Section 1

1.1 Lloyd's Register (hereinafter referred to as 'LR'), which is recognized under the laws of the United Kingdom as a corporate body and a charity established for the benefit of the community, was founded in 1760. It was established for the purpose of producing a faithful and accurate Classification of Merchant Shipping. It now primarily produces Classification Rules.

1.2 Classification services are delivered to clients by a number of other members of the Lloyd's Register Group, including: Lloyd's Register EMEA, Lloyd's Register Asia, Lloyd's Register North America, Inc., and Lloyd's Register Central and South America Limited.

1.3 The Lloyd's Register Group (hereinafter referred to as 'the LR Group') comprises charities, other forms of organisation and non-charitable companies, with the latter supporting the charities in their main goal of enhancing the safety of life and property, at sea, on land and in the air, for the benefit of the public and the environment.

Section 2

2.1 LR remains the sole classification society in the LR Group. LR is managed by a corporate trustee Lloyd's Register Trustees Limited (hereinafter referred to as 'LR's trustee').

LR's trustee has:

Appointed a Classification Committee and determined its powers and functions;
Appointed Technical Committees and determined their powers, functions and duties.

2.2 The LR Group has established National and Area Committees in the following:

Countries:
Australia (via Lloyd's Register Asia)
Canada (via Lloyd's Register North America, Inc.)
China (via Lloyd's Register Asia)
Egypt (via Lloyd's Register EMEA)
Federal Republic of Germany
(via Lloyd's Register EMEA)
France (via Lloyd's Register EMEA)
Italy (via Lloyd's Register EMEA)
Japan (via Lloyd's Register Asia)
New Zealand (via Lloyd's Register Asia)
Poland (via Lloyd's Register (Polska) Sp zoo)
Spain (via Lloyd's Register EMEA)
United States of America (via Lloyd's Register North America, Inc.)

Areas:
Benelux (via Lloyd's Register EMEA)
Central America (via Lloyd's Register Central and South America Ltd)
Nordic Countries (via Lloyd's Register EMEA)
South Asia (via Lloyd's Register Asia)
Asian Shipowners (via Lloyd's Register Asia)
Greece (via Lloyd's Register EMEA)

■ *Section 3*

3.1 LR's Technical Committee is at present composed of:

		TOTAL
Ex officio members:		
•	The Chairman of Lloyd's Register Holdings (LRH)	1
•	The Chairman of the Classification Committee	1
Members Nominated by:		
•	The General Committee of Trustees of LRH	18
•	The Royal Institution of Naval Architects	2
•	The Institution of Engineers and Shipbuilders in Scotland	2
•	The Institute of Marine Engineers	2
•	The Institution of Mechanical Engineers	2
•	The Shipbuilders' and Shiprepairers' Association	2
•	The Short Sea Group of the Chamber of Shipping	1
•	The Society of Consulting Marine Engineers and Ship Surveyors	1
•	The Institute of Materials	1
•	The UK Steel Association	1
•	The Honourable Company of Master Mariners	2
•	The Institution of Electrical Engineers	1
•	Federation of British Electrotechnical and Allied Manufacturers' Associations	1
•	The Technical Committee	18
•	The Technical Committee (from other countries)	18
•	The Institute of Refrigeration	1
•	International Oil Companies	2
•	Association of European Shipbuilders and Shiprepairers	1
•	Greek Shipping Co-operation Committee	1
		79

3.2 In addition to the foregoing:

(a) Each National or Area Committee may appoint a representative to attend meetings of the Technical Committee.

(b) A maximum of five representatives from National Administrations may, with the consent of the Technical Committee, be co-opted to serve on the Technical Committee. Such representatives may also be elected as members of the Technical Committee under one of the categories identified in 3.1.

(c) Further persons may, with the consent of the Technical Committee, be co-opted to serve on the Technical Committee.

3.3 All elections are subject to confirmation by LR's trustee.

3.4 The function of the Technical Committee is to consider any technical problems connected with LR's business and with the exception of changes necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies, any proposed alterations in the existing Rules and to frame new Rules for classification as deemed necessary.

3.5 The term of office of the Chairman and of all members of the Technical Committee is five years. Members may serve one additional term of office with the approval of LR's trustee. The term of the Chairman may be extended with the approval of LR's trustee.

3.6 In the case of continuous non-attendance of a member, the Technical Committee may withdraw his/her membership.

3.7 Meetings of the Technical Committee are convened as often and at such times and places as is necessary, but there is to be at least one meeting in each year.

3.8 Any proposal of the Technical Committee involving any alteration in, or addition to, Rules for Classification is referred to LR's Trustee which has agreed to seek the comments of the Lloyd's Register Holding's General Committee of Trustees before adopting the proposal.

3.9 The Technical Committee is empowered to:

(a) appoint sub-Committees or panels; and

(b) co-opt to the Technical Committee, or to its sub-Committees or panels, representatives of any organization or industry or private individuals for the purpose of considering any particular problem.

■ *Section 4*

4.1 LR's Naval Ship Technical Committee (hereinafter referred to as 'the NSTC') is at present composed of up to 50 members and includes nominees of:

- The Royal Navy and the UK Ministry of Defence;
- The Defence Evaluation and Research Agency;
- UK Shipbuilders, Ship Repairers and Defence Industry;
- Overseas Governments and Governmental Agencies;
- Overseas Shipbuilders, Ship Repairers and Defence Industries;
- Various maritime bodies and institutions, nominated by the NSTC;
- The Chairman of LRH and Chairman of the Classification Committee who are *ex officio* members.

4.2 All elections are subject to confirmation by LR's trustee.

4.3 All members of the NSTC are to hold security clearance from their National Authority for the equivalent of NATO CONFIDENTIAL. All material is to be handled in accordance with NATO Regulations or, for non-NATO countries, an approved equivalent. No classified material shall be disclosed to any third party without the consent of the originator.

4.4 The term of office of the NSTC Chairman and of all members of the NSTC is five years. Members may serve one additional term of office with the approval of LR's trustee. The term of the Chairman may be extended with the approval of LR's trustee.

4.5 In the case of continuous non-attendance of a member, the NSTC may withdraw that person's membership.

4.6 The function of the NSTC is to consider technical issues connected with Naval Ship matters and to approve proposals for new Naval Ship Rules, or amendments to existing Naval Ship Rules.

4.7 Meetings of the NSTC are convened as necessary but there will be at least one meeting per year.

4.8 Following approval by the NSTC, details of new Rules (or amendments) will be submitted to LR's trustee which will seek comments from LRH's General Committee of Trustees before adopting any changes.

■ *Section 5*

5.1 LR has the power to adopt, and publish as deemed necessary, Rules relating to Classification and has (in relation thereto) provided the following:

(a) Except in the case of a special directive by LR's trustee, no new Regulation or alteration to any existing Regulation relating to classification or to class notations is to be applied to existing ships.

(b) Except in the case of a special directive by LR's trustee, or where changes necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies are concerned, no new Rule or alteration in any existing Rule is to be applied compulsorily after the date on which the contract between the ship builder and shipowner for construction of the ship has been signed, nor within six months of its adoption. The date of 'contract for construction' of a ship is the date on which the contract to build the ship is signed between the prospective shipowner and the ship builder. This date and the construction number (i.e. hull numbers) of all the vessels included in the contract are to be declared by the party applying for the assignment of class to a newbuilding. The date of 'contract for construction' of a series of sister ships, including specified optional ships for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective shipowner and the ship builder. In this section a 'series of sister ships' is a series of ships built to the same approved plans for classification purposes, under a single contract for construction. The optional ships will be considered part of the same series of sister ships if the option is exercised not later than 1 year after the contract to build the series was signed. If a contract for construction is later amended to include additional ships or additional options, the date of 'contract for construction' for such ships is the date on which the amendment to the contract is signed between the prospective shipowner and the ship builder. The amendment to the contract is to be considered as a 'new contract'. If a contract for construction is amended to change the ship type, the date of 'contract for construction' of this modified vessel, or vessels, is the date on which the revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder. Where it is desired to use existing approved ship or machinery plans for a new contract, written application is to be made to LR. Sister ships may have minor design alterations provided that such alterations do not affect matters related to classification.

(c) That it will, in all cases, consult with LRH's General Committee of Trustees before passing any Rule amendment.

(d) All reports of survey are to be made by Surveyors authorised by members of the LR Group to survey and report (hereinafter referred to as 'the Surveyors') according to the form prescribed, and submitted for the consideration of the Classification Committee.

(e) Information contained in the reports of classification and statutory surveys will be made available to the relevant owner, National Administration, Port State Administration, P&I Club, hull underwriter and, if authorized in writing by that owner, to any other person or organization.

(f) Information relating to the status of classification and statutory surveys and suspensions/withdrawals of class together with any associated conditions of class will be made available as required by applicable legislation or court order.

(g) A Classification Executive consisting of senior members of LR's Classification Department staff shall carry out whatever duties that may be within the function of the Classification Committee that the Classification Committee assigns to it.

■ *Section 6*

6.1 No LR Group employee is permitted under any circumstances, to accept, directly or indirectly, from any person, firm or company, with whom the work of the employee brings the employee into contact, any present, bonus, entertainment or honorarium of any sort whatsoever which is of more than nominal value or which might be construed to exceed customary courtesy extended in accordance with accepted ethical business standards.

■ *Section 7*

7.1 LR has power to withhold or, if already granted, to suspend or withdraw any class (or to withhold any certificate or report in any other case), in the event of non-payment of any fee to any member of the LR Group.

■ *Section 8*

8.1 When providing services LR does not assess compliance with any standard other than the applicable LR Rules, international conventions, and other standards agreed in writing.

8.2 In providing services, information or advice, the LR Group does not warrant the accuracy of any information or advice supplied. Except as set out herein, LR will not be liable for any loss, damage or expense sustained by any person and caused by any act, omission, error, negligence or strict liability of any of the LR Group or caused by any inaccuracy in any information or advice given in any way by or on behalf of the LR Group even if held to amount to a breach of warranty. Nevertheless, if the Client uses LR's services or relies on any information or advice given by or on behalf of the LR Group and as a result suffers loss, damage or expense that is proved to have been caused by any negligent act, omission or error of the LR Group or any negligent inaccuracy in information or advice given by or on behalf of the LR Group, then a member of the LR Group will pay compensation to the client for its proved loss up to but not exceeding the amount of the fee (if any) charged for that particular service, information or advice.

8.3 Notwithstanding the previous clause, the LR Group will not be liable for any loss of profit, loss of contract, loss of use or any indirect or consequential loss, damage or expense sustained by any person caused by any act, omission or error or caused by any inaccuracy in any information or advice given in any way by or on behalf of the LR Group even if held to amount to a breach of warranty.

8.4 Any dispute about LR's services is subject to the exclusive jurisdiction of the English courts and will be governed by English law.

■ *Section 1* Conditions for classification

1.1 General

1.1.1 The *Rules and Regulations for the Classification of Special Service Craft* (hereinafter referred to as the Rules for Special Service Craft), are applicable to those types of craft which are defined in 2.1. Where the word craft is used in the text of the Rules, it is to be taken as being applicable to yachts and other craft as stated herein unless specifically indicated otherwise.

1.1.2 The Rules are framed on the understanding:

(a) that the craft will at all times be properly loaded. They do not, unless stated or implied in the class notation, provide for special distributions or concentrations of loading associated with the operation of the craft. Lloyd's Register (hereinafter referred to 'LR') may require additional strengthening to be fitted in any craft, which, in their opinion, would otherwise be subjected to severe stresses due to particular features in the design or operation, or where it is desired to make provision for exceptional loading conditions. In such cases particulars and details of the required loadings are to be submitted for consideration,

(b) that the craft will at all times be properly handled, with particular reference to the placing on board of persons and equipment and the reduction of speed in heavy weather,

(c) that compliance with the Rules does not relieve the designer of his responsibilities to his client for compliance with the specification and the requirements for the overall design and in service performance of the craft,

(d) that the craft will not be operated outside of the para-meters specified in any operational envelope which may have been assigned, without the prior agreement of LR.

1.1.3 New craft built in accordance with the Rules, or in accordance with requirements equivalent thereto, will be assigned a class in the appropriate *Register Book* and will continue to be classed so long as they are found, upon examination at the prescribed surveys, to be maintained in accordance with the requirements of the Rules. Classification will be conditional upon compliance with LR's requirements for both hull and machinery.

1.1.4 The class notations of yachts will be recorded on the ClassDirect Live website. The class notations of other craft will be recorded on the ClassDirect Live website in the *Register of Ships.*

1.1.5 LR, in addition to requiring compliance with the Rules, will, in general, require to be satisfied that craft are suitable for the geographical or other limits or conditions of the service contemplated.

1.1.6 Loading conditions and any other preparations required to permit a craft with a notation specifying some service limitation to undertake a sea-going voyage, either from port of building to service area or from one service area to another, are to be in accordance with arrangements agreed by LR prior to the voyage.

1.1.7 Any damage, defect, breakdown or grounding, which could invalidate the conditions for which a class has been assigned, is to be reported to LR without delay.

1.1.8 Where the provision of loading or stress monitoring equipment has been required by LR as the result of local, longitudinal or transverse strength calculations and the imposition of operating limitations, the necessary loading guidance information and operating instructions are to be incorporated in the relevant manuals supplied to the Master.

1.1.9 Where an onboard computer system having longitudinal strength computation capability, which is required by the Rules, is provided on a new craft, or newly installed on an existing craft, then the system is to be certified in respect of longitudinal strength use in accordance with LR's document entitled *Approval of Longitudinal Strength and Stability Calculation Programs.*

1.1.10 Where an onboard computer system having stability computation capability is provided on a new craft, then the system is to be certified in respect of stability aspects in accordance with LR's document entitled, *Approval of Longitudinal Strength and Stability Calculation Programs*. When provided, an onboard computer system having stability computation capability is to carry out the calculations and checks necessary to assess compliance with all the stability requirements applicable to the craft on which it is installed.

1.1.11 For craft, the arrangements and equipment of which are required to comply with the requirements of the:

- International Convention on Load Lines, 1966:
- International Convention for the Safety of Life at Sea, 1974 and its protocol of 1978, which includes the International Code of Safety for High Speed Craft:
- International Convention for the Prevention of Pollution from ships, 1974, as modified by the Protocol of 1978 relating thereto:

and applicable Amendments thereto, the Committee requires the applicable Convention Certificates to be issued by a National Administration, or by LR, or by an IACS Member when so authorized. Safety Management Certificates in accordance with the provisions of the International Safety

Management Code (ISM Code) may be issued by an organization complying with IMO Resolution A.739(18) and authorized by the National Authority with which the craft is registered. Cargo Ship Radio Certificates may be issued by an organization authorized by the National Authority with which the craft is registered.

1.1.12 In the case of dual classed craft, Convention certificates may be issued by the other classification society with which the craft is classed provided this is recognised in a formal Dual Class Agreement with LR and provided the other classification society is also authorized by the National Authority.

1.1.13 Yachts with an overall length, L_{OA}, as defined in Pt 3, Ch 1, of 24 m and over, having a service type notation of **Yacht**, *see* 3.6.2, will be assigned class only after it has been demonstrated that the intact stability of the yacht complies with the applicable standards, *see* Pt 4, Ch 2,8 and Ch 3,10, or the requirements of the National Administration. Possession of a Load Line Certificate issued in accordance with the requirements of the International Convention on Load Lines, 1966, will be accepted as evidence of compliance, *see* 1.1.11.

1.1.14 All yachts, *see* 3.6.2, will be assigned class only after it has been demonstrated that their subdivision is sufficient to satisfy a one compartment standard of damage stability commensurate with that defined in SOLAS 1974, *see* Pt 4, Ch 2,9 or the requirements of the National Administration.

1.2 Application

1.2.1 Except in the case of a special directive by the Committee, no new Regulation or alteration to any existing Regulation relating to character of classification or to class notations is to be applied to existing craft.

1.3 Interpretation of the Rules

1.3.1 The interpretation of the Rules is the sole responsibility, and at the sole discretion, of LR.

1.4 Scope of classification

1.4.1 Classification covers the structural design, watertight integrity and standard of construction of the hull and construction, installation and testing of the propulsion machinery, essential auxiliary machinery, essential piping and electrical systems to the extent indicated within these Rules.

1.4.2 Outfit, other than that covered by 1.4.1, general finish, noise levels, vibration (other than shaft vibration where applicable), trim, design speed and stability, except as mentioned in 1.1.11, 1.1.13 and 1.1.14 are outside the scope of classification.

1.4.3 Where a craft is to be fitted with sails, the masts, rigging and sail arrangements are left to the judgment and experience of the Owner, the Builders and the designers, and LR does not accept responsibility for them. However, for classification purposes the attending Surveyor must be satisfied that they are being maintained in a satisfactory condition.

1.4.4 Where a craft is so badly damaged that class has to be suspended, LR is prepared to assist the Owner with advice if requested.

1.4.5 The attention of Owners and Builders is drawn to statutory requirements which may be imposed by the relevant National Administration and which may not be within the scope of classification.

1.5 Client's responsibilities

1.5.1 The Client is to give LR's Surveyors every facility and necessary access to carry out their survey duties. The Client should familiarise himself with the relevant LR Rules and, where appropriate, arrange that all sub-contractors, suppliers of components, materials or equipment do the same.

1.5.2 The survey procedures undertaken by LR when providing services are on the basis of periodical visits involving both monitoring and direct survey, and LR's Surveyors will not be in continual attendance at LR's Client's premises. As construction and outfitting are continuous processes, the Builder has the overall responsibility to his client to ensure and document that the requirements of the Rules, approved drawings and any agreed amendments made by the attending LR Surveyors have been complied with.

■ *Section 2* Scope of the Rules

2.1 Applicable craft types

2.1.1 The Rules are applicable to the following craft types constructed from steel, aluminium alloy, composite materials or combinations of these materials:

(a) High speed craft.
(b) Light displacement craft.
(c) Multi-hull craft.
(d) Yachts of overall length, L_{OA}, 24 m or greater.
(e) Craft with draught to depth ratio less than or equal to 0,55.

2.1.2 The following craft types will be considered upon request on the basis of the Rules:

(a) Amphibious air cushion vehicles.
(b) Rigid inflatable boats.
(c) Hydrofoil craft.
(d) Foil assisted craft.
(e) Craft as defined 2.1.1(a) to (e) constructed from wood or wood/composite combinations.
(f) Other craft constructed from composite materials.
(g) Craft with a Rule length, L_R, less than 24 m and draught to depth ratio greater than 0,55.

2.1.3 Existing yachts, regardless of length, are subject to the survey requirements defined in Chapter 4.

2.1.4 The Rules incorporate those requirements of the International Convention for the Safety of Life at Sea, 1974 as amended (SOLAS 74) Chapter X – Safety Measures for High Speed Craft (International Code of Safety for High Speed Craft) hereinafter referred to as the HSC code, as applicable to the classification of such craft.

2.1.5 At the discretion of LR craft types which are specifically covered by LR's *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) or other LR Rules and Regulations for Classification may be considered for classification in accordance with these Rules and Regulations.

2.1.6 Where any aspect of the design or construction is not covered by the Rules, the relevant requirements of the Rules for Ships or the *Rules and Regulations for the Classification of Naval Ships* (hereinafter referred to as the Rules for Naval Ships) will be applied as considered necessary.

2.2 Definitions

2.2.1 For the purpose of the Rules, the definitions given in 2.2.2 to 2.2.29 will apply.

2.2.2 **Air Cushion Vehicle.** An Air Cushion Vehicle (ACV) is a craft such that the whole or a significant part of its weight can be supported, whether at rest or in motion, by a continuously generated cushion of air dependent for its effectiveness on the proximity of the surface over which the craft operates.

2.2.3 **Assisted craft.** An assisted craft is any craft operating on a route where it has been demonstrated to the satisfaction of the Administrations concerned that there is a high probability that in the event of an evacuation at any point of the route, all passengers and crew can be rescued safely within the time specified in the HSC Code.

2.2.4 **Catamaran.** A catamaran is a craft with twin-hulls linked by a bridging structure.

2.2.5 **Composite materials.** Composite materials are those construction materials consisting principally of fibre reinforced plastics.

2.2.6 **Design waterline** is the waterline corresponding to the maximum operational weight of the craft with no lift or propulsion machinery active.

2.2.7 **Foil assisted craft.** A foil assisted craft is a craft designed such that a significant part of its weight, whilst in motion, is supported by hydrodynamic lift generated by foils.

2.2.8 **High speed craft.** A high speed craft is a craft capable of maximum speed, V, *see* 2.2.11, not less than:

$V = 7{,}19\ \nabla^{1/6}$ knots

where

∇ = moulded displacement, in m^3, of the craft corresponding to the design waterline.

2.2.9 **Hydrofoil craft.** A hydrofoil craft is a craft which is supported above the water surface in non-displacement mode by hydrodynamic forces generated by foils.

2.2.10 **Light displacement craft.** A light displacement craft is a craft with a displacement not exceeding:

$\Delta = 0{,}04(L_R\,B)^{1{,}5}$ tonnes

where

L_R and B are defined in Pt 3, Ch 1.

2.2.11 **Maximum speed.** Maximum speed is the speed, in knots, achieved at the maximum continuous power for which the craft is certified at maximum operational weight and in smooth water.

2.2.12 **Mono-hull craft.** A mono-hull craft is a craft whose single hull may be of displacement form or of a semi-planing or planing form subject to some support by hydrodynamic lift.

2.2.13 **Multi-hull craft.** A multi-hull craft is a craft with two or more hulls linked by a bridging structure which may be of displacement form or of a semi-planing or planing form subject to some support by hydrodynamic lift.

2.2.14 **Operational speed.** Operational speed is the speed, in knots, corresponding to that permitted by the operational envelope. For High Speed Craft it is not more than 90 per cent of the maximum speed.

2.2.15 **Operational envelope.** The operational envelope defines the craft's service in terms of operational speeds, wave heights, displacements, service area and time required to seek refuge.

2.2.16 **Passenger.** A passenger is every person other than:

(a) The Master and the members of the crew or other persons employed or engaged in any capacity on board a craft on the business of that craft, and
(b) a child under one year of age.

2.2.17 **Passenger craft.** A passenger craft is a craft which carries more than twelve passengers.

2.2.18 **Patrol craft.** A patrol craft is a craft which may be operated by the harbour, police, customs, military authorities, search and rescue or similar organisations.

2.2.19 **Pilot launch.** A pilot launch is a craft designed to come alongside ships whilst at sea to embark or disembark pilots.

2.2.20 **Place of refuge.** A place of refuge is any naturally or artificially sheltered area which may be used as a shelter by a craft under conditions likely to endanger its safety.

2.2.21 **Range to refuge.** Range to refuge is the maximum allowable distance in nautical miles, measured along the shortest safe navigational track from any point on the intended voyage route of the craft to the nearest accessible harbour or place of refuge.

2.2.22 **Reasonable weather.** Reasonable weather is defined as wind strengths of force six or less on the Beaufort scale, associated with:

(a) Sea states within the operational envelope which are sufficiently moderate to ensure that green water is taken on board at infrequent intervals only or not at all.

(b) Motions such as do not impair the efficient operation of the craft and do not significantly reduce passenger comfort or safety or impose any undue loads on any cargo carried.

2.2.23 **Rigid Inflatable Boat.** A Rigid Inflatable Boat (RIB) is a craft combining a rigid hull enclosed by a watertight self-draining deck situated above the deepest operational load waterline and provided with a gas, air or foam-filled flotation collar/fender at the edge of the deck above the hull to improve the stability and to augment the reserve of buoyancy and sea-keeping ability of the rigid hull.

2.2.24 **Service craft.** Service craft is any craft within the scope of the Rules other than a yacht or an amphibious air cushion vehicle.

2.2.25 **Small Waterplane Area Twin Hull Ship.** A Small Waterplane Area Twin Hull Ship (SWATH) is a twin-hulled craft characterised by bulbous lower hulls (torpedoes) and relatively narrow struts connecting them to the haunches and deck structure.

2.2.26 **Surface Effect Ship.** A Surface Effect Ship (SES) is an air-cushion vehicle whose cushion is totally or partially retained by permanently immersed rigid structures.

2.2.27 **Unassisted craft.** An unassisted craft is any craft other than an assisted craft, with machinery and safety systems arranged such that, in the event of damage disabling any essential machinery and safety systems in one compartment, the craft retains the capability to navigate safely as defined in the HSC Code.

2.2.28 **Wave piercer.** A wave piercer is a particular type of catamaran with lower hulls of a displacement or semi-displacement form that provide a positive freeboard when at rest in smooth water but which are expected to become partially submerged when advancing in waves.

2.2.29 **Yacht.** A yacht is a recreational craft used for sport or pleasure and may be propelled mechanically, by sail or by a combination of both.

2.2.30 **Workboat.** A workboat is a general purpose service craft which may be adapted for duties such as line handling, towing, tender, survey, fishing, oil spill recovery, or diving support.

■ *Section 3*
Character of classification and class notations

3.1 General

3.1.1 This Section details the character symbols and notations which comprise the class assigned to special service craft.

3.1.2 The operational envelope assigned to craft built and classed in accordance with the Rules will be included in the operational manual of the craft where such a manual is required by the Rules. A reference to the operational envelope will be made in the Classification Certificate.

3.1.3 Craft built and classed in accordance with the Rules for restricted service but which are not assigned an operational envelope will have their geographical limits included in the Classification Certificate.

3.2 Character symbols

3.2.1 All craft, when classed, will be assigned a character of classification comprising one or more character symbols as applicable, e.g. **✠100A1 SSC.**

3.2.2 A full list of character symbols for which craft may be eligible is as follows:

✠ This distinguishing mark will be assigned, at the time of classing, to new craft constructed under LR's Special Survey, in compliance with the Rules, and to the satisfaction of the Committee.

$\overline{✠}$ This distinguishing mark will be assigned, at the time of classing, to new craft constructed under LR's Special Survey in accordance with plans approved by another recognized classification society.

100 This character figure will be assigned to all craft considered suitable for sea-going service except those in Service Group 1 (*See* 3.5.5).

A This character letter will be assigned to all craft which have been built or accepted into class in accordance with LR's Rules and Regulations, and which are maintained in good and efficient condition.

1 This character figure will be assigned to:

(a) Craft having on board, in good and efficient condition, anchoring and/or mooring equipment in accordance with the Rules.

(b) Craft classed for a specific service, having on board, in good and efficient condition, anchoring and/or mooring equipment approved by the Committee as suitable and sufficient for the particular service.

N This character letter will be assigned to craft on which the Committee has agreed that anchoring and mooring equipment need not be fitted in view of their particular service.

T This character letter will be assigned to ships which are intended to perform their primary designed service function only while they are anchored, moored, towed or linked, and which have, in good and efficient condition, adequately attached anchoring, mooring, towing or linking equipment which has been approved by the Committee as suitable and sufficient for the intended service.

SSC These character letters will be assigned to craft indicating that the craft has been constructed or accepted into class on the basis of the Rules.

3.2.3 For classification purposes the character figure **1** or the character letter **N** is to be assigned.

3.2.4 In cases where the anchoring and/or mooring equipment is found to be seriously deficient in quality or quantity, the class of the craft will be liable to be withheld.

3.3 Class notations (hull)

3.3.1 When considered necessary by the Committee, or when requested by an Owner and agreed by the Committee, a class notation will be appended to the character of classification assigned to the craft. The class notation will consist of one of, or a combination of:

(a) a high speed craft notation;
(b) a light displacement craft notation;
(c) a service area restriction notation;
(d) a service type notation; and
(e) a craft type notation;
(f) other hull notations;

e.g.

✠**100A1** SSC Passenger (A) Catamaran
HSC G3 'service area'
✠**100A1** SSC Yacht Catamaran
LDC G5.

3.3.2 A list of class notations (hull) for which a craft may be eligible is given in 3.4 to 3.10.

3.4 High speed craft and light displacement craft notations

3.4.1 **HSC – High speed craft notation.** This class notation will be assigned to high speed craft as defined in 2.2.8.

3.4.2 **LDC – Light displacement craft notation.** This class notation will be assigned to light displacement craft as defined in 2.2.10.

3.5 Service area restriction notations

3.5.1 All craft classed under the Rules will be assigned a service area restriction notation **G** followed by a number e.g. **G1.** Craft classed under the Rules for service groups **G1** to **G5** are not suitable for unrestricted service except as noted in the service area restriction notation, *see* 3.5.5.

3.5.2 Service area restriction notations, given in 3.5.5, are expressed in terms of range to refuge in nautical miles as defined in 2.2.20.

3.5.3 Where craft are required to satisfy limitations in respect of the maximum duration of time to a place of refuge from any point during the voyage, this time is to be determined by dividing the range to refuge by the permitted operational speed of the craft (when fully laden) in the prevailing conditions as imposed by the operational envelope.

3.5.4 For craft that are designed in accordance with an operational envelope, typically **HSC** or **LDC** craft as defined in 3.4:

- these craft are to be operated at reduced speeds and are to seek calmer waters or refuge when the weather conditions deteriorate or are predicted to deteriorate such that the limits of the operational envelope are exceeded.

For craft that are not assigned an operational envelope:

- these craft are to be operated at reduced speeds and are to seek calmer waters or refuge when the weather conditions deteriorate or are predicted to deteriorate.

All craft are to be aware of the weather forecast for the proposed and current areas of operation and area of refuge.

3.5.5 The service area restriction notations defined below describe the service area restriction for which the craft has been approved and constructed.

G1 **Service Group 1** covers craft intended for service in sheltered waters adjacent to sandbanks, estuaries, reefs, breakwaters or other coastal features and in similarly sheltered waters between islands in reasonable weather where the range to refuge is, in general, five nautical miles or less. The geographical limits of the intended service are to be identified by the Builder and agreed with LR. Craft in this group are not eligible for the assignment of the character figure **100.**

G2 **Service Group 2** covers craft intended for service in reasonable weather, in waters where the range to refuge is 20 nautical miles or less. This group will usually cover craft intended for service in coastal waters, for which geographical limits are to be identified by the Builder and agreed with LR.

G3 **Service Group 3** covers craft intended for service in waters where the range to refuge is 150 nautical miles or less. The geographical limits of the intended service are to be reported to LR.

G4 **Service Group 4** covers craft intended for service in waters where the range to refuge is 250 nautical miles or less. The geographical limits of the intended service are to be reported to LR.

G5 **Service Group 5** covers craft intended for service in waters where the range to refuge is 350 nautical miles or less. The geographical limits of the intended service are to be reported to LR.

G6 **Service Group 6** covers yachts and steel patrol craft having unrestricted service.

3.5.6 Consideration may be given to requests for an increase in the permissible range to refuge subject to:

(a) The specific geographic limits and the period over which the extended service is to be operated being defined.

(b) Satisfactory statistical data in respect of wave height, being provided to demonstrate that the craft will be suitable for the extended service.

(c) Equipment consistent with that required for the extended service being provided onboard during the period of operation.

(d) Any maximum duration of voyage limitations imposed by 3.5.3 not being exceeded during the extended service.

3.6 Service type notations

3.6.1 The service type notation will be recorded in the appropriate *Register Book* indicating the primary purpose for which the craft has been designed and constructed.

3.6.2 A list of service type notations for which craft may be eligible is given below:

Cargo (A) This notation will be assigned to cargo craft other than Cargo (B) craft.

Cargo (B) This notation will be assigned to unassisted high speed cargo craft of 500 gross tons and over which do not proceed in the course of their voyage more than eight hours at operational speed from a place of refuge when fully laden. These craft correspond to 'Cargo Craft' as defined in the HSC Code.

Passenger This notation will be assigned to passenger craft other than **Passenger (A)** or **Passenger (B)** craft.

Passenger (A) This notation will be assigned to assisted high speed craft carrying not more than 450 passengers on board and which do not proceed in the course of their voyage more than four hours at operational speed from a place of refuge when fully laden. These craft correspond to 'Category A Craft' as defined in the HSC Code.

Passenger (B) This notation will be assigned to unassisted high speed craft which may carry more than 450 passengers on board and which do not proceed in the course of their voyage more than four hours at operational speed from a place of refuge when fully laden. These craft correspond to 'Category B Craft' as defined in the HSC Code.

Patrol This notation will be assigned to patrol craft complying with the relevant requirements of the Rules.

Pilot This notation will be assigned to pilot launches complying with the relevant requirements of the Rules.

Yacht This notation will be assigned to all yachts.

Workboat This notation will be assigned to workboats complying with the relevant requirements of the Rules.

3.7 Craft type notations

3.7.1 The craft type notation will be recorded in the appropriate *Register Book* indicating the type of hull form and mode of operation for which the craft has been designed and constructed.

3.7.2 A list of craft type notations for which craft may be eligible is given below:

ACV This notation will be assigned to amphibious air cushion vehicles.

Catamaran This notation will be assigned to catamarans including wave piercers.

Hydrofoil This notation will be assigned to hydrofoil craft.

Mono This notation will be assigned to mono-hull craft other than amphibious air cushion vehicles, hydrofoils and rigid inflatable boats.

Multi This notation will be assigned to multi-hull craft other than catamarans, swaths and surface effect ships.

RIB This notation will be assigned to rigid inflatable boats.

SES This notation will be assigned to surface effect ships.

Swath This notation will be assigned to small water-plane area twin hull ships.

3.7.3 Where craft indicated in 3.7.2 are foil assisted the letters (FA) may be appended to the Craft Type Notation.

3.8 Other hull notations

3.8.1 **Ice class notation.** A class notation for navigation in first year ice conditions will be specially considered.

3.8.2 ***IWS.** This notation (In-water Survey) may be assigned to a craft where the applicable requirements of LR's Rules and Regulations are complied with. (*See* Ch 3,4.3 and Ch 4,3.3, *see also* Pt 3, Ch 3,2.37).

3.8.3 **Special duties notation.** A special duties notation will be recorded in the *Register Book* indicating that the craft has been designed, modified or arranged for special duties other than those implied by the type notation. Craft with special duties notations are not thereby prevented from performing any other duties for which they may be suitable.

3.8.4 **Special features notation.** A notation indicating that the craft incorporates special features which significantly affect the design, e.g. movable decks.

3.8.5 **LI.** This notation will be assigned where an approved loading instrument has been installed as a classification requirement.

3.9 Class notations (machinery)

3.9.1 The following class notations may be assigned as considered appropriate by the Committee:

✠ LMC This notation will be assigned when the propelling and essential auxiliary machinery has been constructed, installed and tested under LR's Special Survey and in accordance with LR's Rules and Regulations.

✠̅ LMC This notation will be assigned when the propelling and essential auxiliary machinery has been constructed under the survey of a recognized authority in accordance with the Rules and Regulations equivalent to those of LR. In addition, the whole of the machinery will be required to have been installed and tested under LR's Special Survey in accordance with LR's Rules and Regulations.

[✠]LMC This notation will be assigned when the propelling arrangements, steering systems, pressure vessels and the electrical equipment for essential systems have been constructed, installed and tested under LR's Special Survey and are in accordance with LR's Rules and Regulations. Other items of machinery for propulsion and electrical power generation including propulsion gearing arrangements and other auxiliary machinery for essential services that are in compliance with LR Rules and supplied with the manufacturer's certificate will be acceptable under this notation. The system arrangements of propelling and essential auxiliary machinery are required to be appraised by LR, and found to be acceptable to LR. *See* 3.11.2.

LMC This notation (without ✠) will be assigned when the propelling and essential auxiliary machinery has neither been constructed nor installed under LR's Special Survey but the existing machinery, its installation and arrangement, has been tested and found to be acceptable to LR. This notation is assigned to existing craft in service accepted or transferring into LR class.

MCH This notation will be assigned when the propelling and essential auxiliary machinery has been installed and tested under LR's survey requirements and found to be acceptable to LR. Items of machinery and equipment for propelling and auxiliary machinery for essential services supplied with the manufacturer's certificate will be acceptable under this class notation. The system arrangements of propelling and essential auxiliary machinery are required to be appraised by LR, and found to be acceptable to LR. *See* 3.10.1.

UMS This notation may be assigned when the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto and the arrangements are such that the craft can be operated with the machinery spaces unattended.

CCS This notation may be assigned when the arrangements are such that the machinery may be operated with continuous supervision from a centralized control station. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

3.9.2 Machinery class notations will not be assigned to craft the hulls of which are not classed or intended to be classed with LR.

3.9.3 The notation **✠LMC**, **✠̅LMC, [✠]LMC**, **LMC** (without ✠) and **MCH** will in general not be assigned to non-propelled craft, but individual cases will be considered on their merits.

3.10 Application notes

3.10.1 Propelling and essential auxiliary machinery includes machinery, equipment and systems installed for the craft/yacht to be under seagoing conditions and that are necessary for the following:

(a) Maintaining the watertight and weathertight integrity of the hull and spaces within the hull.
(b) The safety of the craft/yacht, machinery and personnel on board.
(c) The functioning and dependability of propulsion, steering and electrical systems.
(d) The operation and functioning of control engineering systems for the monitoring and safety of propulsion, steering and electrical power systems.
(e) The operation and functioning of emergency machinery and equipment.

3.10.2 **Manufacturer's certificate** for assignment of the **[✠]LMC** notation. Acceptance of the manufacturer's certificate for items of machinery for propulsion (including propulsion gearing with single input/output arrangements) and for electrical power generation and for other auxiliary machinery for essential services is subject to the following:

(a) For a craft: The craft is intended for the carriage of cargo (not passengers), is less than 500 gross tonnage or is of 500 gross tonnage or greater and is not required to comply with international conventions applicable to a craft with unrestricted service.
(b) For a yacht: The yacht has a gross tonnage of less than 500, or has a gross tonnage of 500 or more and is not required to comply with international conventions applicable to a yacht with unrestricted service.
(c) Propulsion power is provided by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(d) Electrical power is provided by generators driven by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(e) The design and manufacturing standards for all machinery and associated systems are the applicable LR Rules.
(f) The machinery and equipment is manufactured under a recognised quality control system.
(g) Propellers, propulsion shafting and multiple input/output gearboxes are not included within the scope of propulsion arrangements for acceptance of a manufacturer's certificate.

3.10.3 **Manufacturer's certificate** for assignment of the **MCH** notation. Acceptance of the manufacturer's certificate for propelling and essential auxiliary machinery is subject to the following:

(a) For a craft: The craft is intended for the carriage of cargo (not passengers), is less than 500 gross tonnage or is of 500 gross tonnage or greater and is not required to comply with international conventions applicable to a craft with unrestricted service.
(b) For a yacht: The yacht is less than 500 gross tonnage or is of 500 gross tonnage or more and is not required to comply with international conventions applicable to a yacht with unrestricted service.
(c) Propulsion power is provided by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(d) Electrical power is provided by generators driven by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(e) The power of any engine or gas turbine is less than 2,250 kW and the cylinder bore of any diesel engine is not greater than 300 mm.
(f) The design and manufacturing standards for machinery and associated systems are the applicable LR Rules or other marine standards acceptable to LR.
(g) The machinery and equipment is manufactured under a recognised quality control system.

3.11 Class notations (Environmental Protection)

3.11.1 The following class notations are associated with the design and operation of a Special Service Craft and may be assigned as considered appropriate by the Committee, on application from the Owners:

EP This notation may be assigned when the design and operation of a Special Service Craft are in accordance with the relevant requirements in Pt 7, Ch 11 of the Rules.

$\overline{\text{EP}}$ This notation may be assigned when the environmental protection provisions of the Special Service Craft are in accordance with the requirements of another recognised classification society and are broadly equivalent to the requirements in Pt 7, Ch 11 of the Rules. Prior to assignment of the notation, an audit, in accordance with the requirements in 4.1.3 and 4.1.4 of Pt 7, Ch 11 of the Rules, is to be undertaken by LR to confirm that the necessary Environmental Protection procedures are in place and implemented effectively.

3.12 Descriptive notes

3.12.1 In addition to any class notations, an appropriate descriptive note may be entered in column 6 of the appropriate *Register Book* indicating the type of craft in greater detail than is contained in the class notation, and/or providing additional information about the craft’s design and construction. This descriptive note is not a LR classification notation and is provided solely for the information of users of the *Register Book*.

3.12.2 The descriptive note **SCM** (Screwshaft Condition Monitoring) may be assigned when oil lubricated screwshaft arrangements with approved oil glands are fitted and the requirements of Ch 3,11.3 or Ch 4,10.3 are complied with.

■ *Section 4* Surveys – General

4.1 Statutory surveys

4.1.1 The Committee will act, when authorized on behalf of Governments, in respect of National and International statutory safety and other requirements.

4.1.2 The Committee will also act, when authorized, in respect of National safety and other requirements relating to craft used for offshore mineral exploration and exploitation.

4.2 New construction surveys

4.2.1 When it is intended to build a craft for classification with LR, constructional plans and all particulars relevant to the hull, equipment and machinery, as detailed in the Rules, are to be submitted for the approval of the Committee before the work is commenced. Any subsequent modifications or additions to the scantlings, arrangements or equipment shown on the approved plans are also to be submitted for approval.

4.2.2 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of the Committee, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the appropriate *Register Book*.

4.2.3 The materials used in the construction of hulls and machinery intended for classification are to be of good quality and free from defects and are to comply with the requirements of the Rules.

4.2.4 The Surveyor is to be satisfied that the capability, organisation and facilities of the Builder are such that acceptable standards can be obtained both for the construction of the craft and the installation of machinery, electrical and control equipment.

4.2.5 In addition to 4.2.4, the hull construction of craft manufactured from composite materials is to be controlled by a documented quality control system covering the Builder's management, organisation and relevant construction processes and inspection procedures, *see* Pt 8, Ch 2.

4.2.6 New craft intended for classification are to be built under LR's Special Survey. The Surveyors are to be satisfied that the materials, workmanship and arrangements are in accordance with the Rules. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be so, are to be rectified.

4.2.7 For compliance with 4.2.6 LR is prepared to consider methods of survey and inspection for hull construction which formally include procedures involving the shipyard management, organization and quality systems as defined in Chapter 2 of Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively.

4.2.8 Copies of approved plans (showing the craft as built), essential certificates and records, required loading and other instruction manuals are to be readily available for use when required by LR's Surveyors and may be required to be kept on board.

4.2.9 After completion, the craft is to be examined afloat, and trials are to be conducted as specified in the Rules.

4.2.10 When the machinery is constructed under LR's Special Survey, this survey is to relate to the period from the commencement of the work until the final test under working conditions. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be unsatisfactory, are to be rectified.

4.2.11 When arrangements are such that essential machinery can be operated by remote and/or automatic control equipment, the control equipment is to be arranged, installed and tested in accordance with the Rules, as applicable.

4.2.12 The date of completion of the Special Survey during construction of craft built under LR's inspection will normally be taken as the date of build to be entered in the appropriate *Register Book*. If the period between launching and commissioning is, for any reason, unduly prolonged, the dates of launching and completion or commissioning may be separately indicated in the appropriate *Register Book*.

4.2.13 When a craft, upon completion, is not immediately commissioned but is laid-up for a period, the Committee, upon application by the Owner, prior to the craft proceeding to sea, will direct an examination to be made by LR's Surveyors which may include a survey in dry-dock. If, as the result of such survey, the hull and machinery be reported in all respects free from deterioration, the subsequent Special Survey and Complete Survey of the machinery will date from the time of such examination.

4.3 Existing craft

4.3.1 **Classification of craft not built under survey.** The requirements of the Committee for the classification of craft which have not been built under LR's Survey are indicated in Ch 3,12 or Ch 4,12 as applicable. Special consideration will be given to craft transferring class to LR from another recognized Classification Society.

4.3.2 **Reclassification.** When reclassification or class reinstatement is desired for a craft for which the class previously assigned by LR has been withdrawn or suspended, the Committee will direct that a survey, appropriate to the age of the craft and the circumstances of the case, be carried out by LR's Surveyors. If, at such survey, the craft be found or placed in a good and efficient condition in accordance with the requirements of the Rules, the Committee will be prepared to consider reinstatement of the original class or the assignment of such other class as may be deemed necessary.

4.3.3 In the case of existing yachts over 15 years of age, the requirements for classification of craft not built under survey or for reclassification will be specially considered.

4.3.4 The Committee reserves the right to decline an application for classification or reclassification where the prior history or condition of the craft indicates this to be appropriate.

4.4 Damages, repairs and alterations

4.4.1 All repairs to hull, equipment and machinery which may be required in order that a craft may retain her class, *see* 1.1.7, are to be carried out to the satisfaction of LR's Surveyors. When repairs are effected at a port, terminal or location where the services of a Surveyor to LR are not available, the repairs are to be surveyed by one of LR's Surveyors at the earliest opportunity thereafter.

4.4.2 When at any survey the Surveyors consider repairs to be immediately necessary, either as a result of damage, or wear and tear, they are to communicate their recommendations at once to the Owner, or his representative. When such recommendations are not complied with, immediate notification is to be given to the Committee by the Surveyors.

4.4.3 When at any survey it is found that any damage, defect, or breakdown (*see* 1.1.7) is of such a nature that it does not require immediate permanent repair, but is sufficiently serious to require rectification by a prescribed date in order to maintain class, a suitable condition of class is to be imposed by the Surveyors and recommended to the Committee for consideration.

4.4.4 If a craft which is classed with LR is to leave harbour limits or protected waters under tow, the Owner is to advise LR of the circumstances prior to her departure.

4.4.5 If a craft which is classed with LR is taken in tow whilst at sea, the Owner is to advise LR of the circumstances at the first practicable opportunity.

4.4.6 Plans and particulars of any proposed alterations to the approved scantlings and arrangements of hull, equipment, or machinery are to be submitted for approval by Owners or Builders or their representatives and such alterations are to be carried out to the satisfaction of LR's Surveyors.

4.4.7 The Owners should notify LR whenever a craft can be examined in dry-dock or on a slipway.

4.5 Existing service craft and yachts – Periodical Surveys

4.5.1 Service craft are to be submitted to the periodical survey requirements as defined in Chapter 3.

4.5.2 Yachts are to be submitted to the periodical survey requirements defined in Chapter 4, except in the case where LR issues Statutory Loadline SAFCON certification or Certificate of Compliance to 'Code of Practice' as a requirement of the National Authority of the country in which the yacht is registered. In these cases they are to be submitted to the periodical survey requirements as defined in Chapter 3.

4.5.3 Annual Surveys are to be held on all craft other than yachts within three months, before or after each anniversary of the completion, commissioning or Special Survey. The date of the last Annual Survey will be recorded on the ClassDirect Live website.

4.5.4 Intermediate Surveys are to be held on all craft other than yachts instead of the second or third Annual Survey after completion, commissioning or Special Survey. The date of the last Intermediate Survey will be recorded on the ClassDirect Live website.

4.5.5 Intermediate Surveys are to be held on yachts between the second and third anniversary after completion, commissioning or Special Survey.

4.5.6 The Owner should notify the Surveyors whenever a craft can be examined in dry-dock or on a slipway. A minimum of two Docking Surveys are to be held in each five-year Special Survey period and the maximum interval between successive Docking Surveys is not to exceed three years. One of the two Docking Surveys required in each five year period is to coincide with the Special Survey. Consideration may be given at the discretion of the Committee to any special circumstances justifying an extension of this interval and the Committee may accept an In-water Survey in lieu of the intermediate docking between Special Surveys (*see* Ch 3,4.3 and Ch 4,3.3). A Docking Survey is considered to coincide with the Special Survey when held within the 15 months prior to the due date of the Special Survey.

4.5.7 The interval between dry-dockings for craft operating in fresh water and for certain non self-propelled craft may at the discretion of the Committee, be greater than that given in 4.5.6.

4.5.8 Attention is to be given to any relevant statutory requirements of the National Authority of the country in which the craft is registered.

4.5.9 The date of the last examination in dry-dock or on a slipway will be recorded on the ClassDirect Live website.

4.5.10 Survey requirements for In-water Surveys are given in Ch 3,4.3 and Ch 4,3.3 as appropriate. The date of the last In-water Survey will be recorded on the ClassDirect Live website.

4.5.11 All craft classed with LR are also to be subjected to Special Surveys. These Surveys become due at five-yearly intervals, the first one five years from the date of build or date of Special Survey for Classification as recorded in the appropriate *Register Book*, and thereafter five years from the date recorded for the previous Special Survey. Consideration can be given at the discretion of the Committee to any exceptional circumstances justifying an extension of the hull classification to a maximum of three months beyond the fifth year. If an extension is agreed the next period of hull classification will start from the due date of the Special Survey before the extension was granted.

4.5.12 Special surveys may be commenced at the fourth Annual Survey or fourth anniversary, as appropriate, after completion, commissioning, or previous Special Survey, and be progressed during the succeeding year with a view to completion by the due date of the Special Survey.

4.5.13 Special Surveys which are commenced prior to their due date are not to extend over a period greater than 12 months, except with the prior approval of the Committee.

4.5.14 Craft which have satisfactorily passed a Special Survey will have a record entered indicating the date. Where the Special Survey is completed more than three months before the due date, the new record of Special Survey will be the final date of survey. In all other cases the date recorded will be the fifth anniversary. In the case of yachts this information will be recorded on the ClassDirect Live website.

4.5.15 At the request of an Owner, the Committee may agree that the Special Survey of the hull be carried out on the Continuous Survey basis, all compartments of the hull being opened for survey and testing, in rotation, with an interval of five years between consecutive examinations of each part. In general, approximately one fifth of the Special Survey is to be completed each year and all the requirements of the particular hull Special Survey must be completed at the end of the five year cycle. If the examination during Continuous Survey reveals any defects, further parts are to be opened up and examined as considered necessary by the Surveyor. For examination of items listed in Ch 3,2.2.16, 2.2.17, 3.2.2, 3.2.3, 3.2.4 or Ch 4,2.2.11, 2.2.12, 2.2.13 as applicable, the intervals for inspection will require to be specially agreed. Craft which have satisfactorily completed the cycle will have a record entered in the *Register Book* indicating the date of completion which will not be later than five years from the last assigned date of Complete Survey of the hull. The agreement for surveys to be carried out on Continuous Survey basis may be withdrawn at the discretion of the Committee.

4.5.16 Complete Surveys of machinery become due at five yearly intervals, the first one five years from the date of build or date of first classification as recorded in the appropriate *Register Book*, and thereafter five years from the date recorded for the previous Complete Survey. Consideration can be given at the discretion of the Committee to any exceptional circumstances justifying an extension of machinery class to a maximum of three months beyond the fifth year. If an extension is agreed to, the next period of machinery class will start from the due date of Complete Survey of machinery before extension was granted. Surveys which are commenced prior to their due date are not to extend over a period greater than 12 months, except with the prior approval of the Committee. Where the complete survey is completed more than three months before the due date, the recorded date of completion will be the final date of survey. In all other cases the date recorded will be the fifth anniversary.

4.5.17 Upon application by an Owner, the Committee may agree to the extension of the survey requirements for main engines, which, by the nature of the craft's normal service, do not attain the number of running hours recommended by the engines' manufacturer for major overhauls within the survey periods given in 4.5.16.

4.5.18 If it is found desirable that any part of the machinery should be examined again before the due date of the next survey, a certificate for a limited period will be granted in accordance with the nature of the case.

4.5.19 When, at the request of an Owner, it has been agreed by the Committee that the Complete Survey of the machinery may be carried out on the Continuous Survey basis, the various items of machinery are to be opened for survey in rotation, so far as is practicable, to ensure that the interval between consecutive examinations of each item will not exceed five years. In general, approximately one-fifth of the machinery is to be examined each year.

4.5.20 If any examination during Continuous Survey reveals defects, further parts are to be opened up and examined as considered necessary by the Surveyor, and the defects are to be made good to his satisfaction.

4.5.21 Upon application by an Owner, The Committee may agree to an arrangement whereby, subject to certain conditions, some items of machinery may be examined by the Chief Engineer of the craft at ports where LR is not represented, or, where practicable, at sea, followed by a limited confirmatory survey carried out at the next port of call where an Exclusive Surveyor is available. Particulars of this arrangement may be obtained from LR's Headquarters.

4.5.22 Where an approved planned maintenance scheme is in operation the confirmatory surveys of machinery as required by 4.5.21 may be held at annual intervals, at which time the records will be checked and the operation of the scheme verified. Particulars of this arrangement may be obtained from any of LR's Offices.

4.5.23 Where condition monitoring equipment is fitted, the Committee, upon application by the Owner, will be prepared to amend applicable Periodical Survey requirements where details of the equipment are submitted and found satisfactory. Where machinery installations are accepted for this method of survey, it will be a requirement that an Annual Survey be held, at which time monitored records will be analysed and the machinery examined under working conditions. An acceptable lubricating oil trend analysis programme may be required as part of the condition monitoring procedures.

4.5.24 Screwshaft and Waterjet Unit Surveys are to be carried out as stated in Ch 3,11 for service craft and Ch 4,10 for yachts.

4.5.25 Boiler surveys and steam pipe surveys, where applicable are to be carried out as stated in accordance with Pt 1, Ch 3,15 and 16 of the Rules for Ships.

4.5.26 Craft of unusual design, type or arrangement may be subject to exceptional survey requirements. Such survey requirements will be detailed at the assignment of classification.

4.6 Existing amphibious air cushion vehicles – Periodical Surveys

4.6.1 Amphibious Air Cushion Vehicles are to be submitted to the periodical survey requirements as defined in Chapter 5.

4.7 Certificates

4.7.1 When the required reports, on completion of the survey of new or existing craft which have been submitted for classification, have been received from the Surveyors and approved by the Committee, a certificate of First Entry of Classification, signed by the Chairman, or the Deputy Chairman and Chairman of the Sub-Committee of Classification, will be issued to Builders or Owners.

4.7.2 A Certificate of Class valid for five years subject to endorsement for Annual and/or Intermediate Surveys, as appropriate, will also be issued to the Owners.

4.7.3 LR's Surveyors are permitted to issue provisional (interim) certificates to enable a craft classed with LR to proceed on her voyage provided that in their opinion it is in a fit and efficient condition. Such certificates will embody the Surveyors' recommendations for continuance of class, but in all cases are subject to confirmation by the Committee.

4.8 Notice of surveys

4.8.1 It is the responsibility of the Owners to ensure that all surveys necessary for the maintenance of class are carried out at the proper time and in accordance with the instructions of the Committee. Information is available to Owners on the ClassDirect Live website.

4.8.2 LR will give timely notice to an Owner about forthcoming surveys by means of a letter or a computer print-out of a craft's *Quarterly Listing of Surveys, Conditions of Class and Memoranda*. The omission of such notice, however, does not absolve the Owner from his responsibility to comply with LR's survey requirements for maintenance of class, all of which are available to Owners on the ClassDirect Live website.

4.9 Withdrawal/Suspension of class

4.9.1 When the class of a craft, for which the Regulation as regards surveys on hull, equipment and machinery have been complied with, is withdrawn by the Committee in consequence of a request from the Owner the notation 'Class withdrawn at Owner's request' (with date) will be assigned.

4.9.2 When the Regulations as regards surveys on the hull, equipment or machinery have not been complied with and the craft is thereby not entitled to retain class, the class will be suspended or withdrawn, at the discretion of the Committee, and a corresponding notation will be assigned.

4.9.3 Class will be automatically suspended and the Certificate of Class will become invalid if the Annual or Intermediate Survey, as appropriate, is not completed within three months of the due date of the survey.

4.9.4 Class will be automatically suspended from the expiry date of the Certificate of Class in the event that the Special Survey has not been completed by the due date and an extension has not been agreed (*see* 4.5.11), or is not under attendance by the Surveyors with a view to completion prior to resuming trading.

4.9.5 When in accordance with 4.4.3 a condition of class is imposed, this will be assigned a due date for completion and the craft's class will be subject to a suspension procedure if the condition of class is not dealt with, or postponed by agreement, by the due date.

4.9.6 When it is found, from the reported condition of the hull or equipment or machinery of a craft, that an Owner has failed to comply with Regulations 1.1.7, 1.1.11, 4.4.1 or 4.4.5 above, the class will be liable to be suspended or withdrawn, at the discretion of the Committee, and a corresponding notation assigned. When it is considered that an Owner's failure to comply with these requirements is sufficiently serious the suspension or withdrawal of class may be extended to include other craft controlled by the same Owner, at the discretion of the Committee.

4.9.7 When any craft proceeds to sea with less freeboard than that approved by the Committee, or when the freeboard marks are placed higher on the sides of the craft than the position assigned or approved by the Committee, or, in cases of craft where freeboards are not assigned, the draught is greater than that approved by the Committee, the class will be liable to be withdrawn or suspended.

4.9.8 When it is found that a craft is being operated in a manner contrary to that agreed at the time of classification, i.e. out with the parameters of the operational envelope, the class will be liable to be automatically withdrawn or suspended.

4.9.9 In all instances of class withdrawal or suspension, the assigned notation, with date of application, will appear in the *Register Book*. In cases where class has been suspended by the Committee and it becomes apparent that the Owners are no longer interested in retaining LR's class, the notation will be amended to withdrawn status. After class withdrawn status has been established in the appropriate *Register Book* for one year, it will be automatically amended to 'classed LR until' (with date). In the case of yachts this information will be recorded on the ClassDirect Live website.

4.9.10 For reclassification and reinstatement of class, *see* 4.3.2 and 4.3.3.

4.10 Survey of craft out of commission

4.10.1 The classification requirements for laid up vessels will be specially considered. Surveys for continuation of class may be required at the discretion of the Committee.

4.11 Appeal from Surveyors' recommendations

4.11.1 If the recommendations of LR's Surveyors are considered in any case to be unnecessary or unreasonable, appeal may be made to the Committee, who may direct a Special Examination to be held.

■ *Section 5* IACS QSCS Audits

5.1 Audit of Surveys

5.1.1 The surveys required by the Regulations may be subject to audit in accordance with the requirements of the International Association of Classification Societies Quality System Certification Scheme.

■ *Section 6* Type Approval/Type testing/ Quality control system

6.1 LR Type Approval – Marine Applications

6.1.1 LR Type Approval is an impartial certification system that provides independent third-party Type Approval Certificates attesting to a product's conformity with specific standards or specifications. It is based on design review and type testing or where testing is not appropriate, a design analysis.

6.1.2 The LR Type Approval System is a process whereby a product is assessed in accordance with a specification, standard or code to check that it meets the stated requirements and through selective testing demonstrates compliance with specific performance requirements. The testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under approval. Thereafter, the producer is required to use Quality Control procedures and processes to ensure that each item delivered is in conformity with that which has been Type Tested.

6.1.3 The selective testing required by 6.1.2 is to include environmental testing applicable to the product's installation on board a craft or yacht classed or intended to be classed with LR.

6.1.4 LR Type Approval does not remove the requirements for inspection and survey procedures required by the Rules for equipment to be installed in craft/yachts classed or intended to be classed with LR. Also, LR Type Approval does not remove the requirement for plan appraisal of a system that incorporates Type Approved equipment where required by the Rules.

6.1.5 LR Type Approval is subject to the understanding that the producer's recommendations and instructions for the product and any relevant requirements of the Rules for the Classification of Special Service Craft are fulfilled.

6.1.6 The producer supplying equipment or components under Quality Control procedures and processes is to have a recognised quality management system certified by an IACS member or Notified Body. The Quality Control procedures and processes are to address the production of the product consistent with 6.3.

6.1.7 Where equipment or components have been Type Approved in accordance with specifications and procedures other than LR's, details of the product, certification and testing are to be submitted for consideration where appropriate.

6.2 Type testing

6.2.1 Type testing is an impartial process that provides independent third-party verification that an item of machinery or equipment has satisfactorily undergone a functional type test.

6.2.2 Type testing is carried out against defined performance and test standards for a defined period of time with test conditions varying between minimum and maximum declared design conditions.

6.2.3 Type testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under assessment.

6.2.4 After type testing, mechanical equipment is to be opened out and inspected for damage or excessive wear.

6.2.5 On application from the manufacturer, type tests may be waived for equipment and machinery that has been proven to be reliable in marine service and where compliance with the current applicable standards can be demonstrated. Equipment and machinery that has been previously type tested with satisfactory testing evidence and certification need not have the type tests repeated where previous testing is in compliance with the current testing standards.

6.2.6 The acceptance of type testing certification is subject to the understanding that the manufacturer's recommendations and instructions for the product and any relevant requirements of the applicable Rules are fulfilled.

6.3 Quality control system

6.3.1 A quality control system for the purposes of LR acceptance of materials and machinery refers to a scheme that covers the operational techniques and activities that is used to demonstrate that the quality requirements for a product are in accordance with declared standards.

6.3.2 The quality control system for a particular product extends to all parties involved in the supply chain from manufacture and testing through to delivery of the product.

6.3.3 LR acceptance of machinery and equipment manufactured under a quality control scheme is dependent on the scheme being maintained through a traceable process involving planned audits and spot inspections at the discretion of LR Surveyors. The purpose of the audits and spot inspections is to ensure that the procedures for manufacture and quality control are being maintained in a satisfactory manner.

6.3.4 The use of a quality control system does not remove the requirements for inspection processes that may be required by the Rules applicable to the equipment being supplied with a manufacturer's certificate. Also the use of a quality control system does not remove the requirement for plan appraisal of equipment or systems where required by the Rules.

■ *Section 7* Classification of machinery for craft/yachts with [✠] LMC or MCH notation

7.1 General

7.1.1 After delivery of machinery and equipment with the manufacturer's certificate to the build yard, Survey at the build yard and Periodical Surveys are to be in accordance with the requirements for craft/yacht built or accepted into class with the ✠**LMC** notation.

7.2 Appraisal and records

7.2.1 To facilitate survey and compilation of classification records, plans and information required for a craft/yacht being accepted into class with the ✠**LMC** notation are to be submitted for appraisal and information. Plans are not required where machinery and equipment has previously been type approved; in these cases it is only necessary to submit details of the machinery and equipment together with details of the previous approval.

7.3 Survey and inspection

7.3.1 The manufacturer's certificate for acceptance of machinery and equipment for assignment of the **[✠]LMC** or **MCH** notation is to be in the English language and include the following information:

(a) Design and manufacturing standard(s) used.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during design, manufacture and testing and any software maintenance.
(d) Details of any type approval or type testing.
(e) Details of installation and testing recommendations for the machinery or equipment.

The manufacturer is to have a recognised quality management system certified by an IACS member or a Notified Body.

7.3.2 The installation and testing of machinery and equipment at the build yard which has been supplied with a manufacturer's certificate is to be in accordance with the requirements applicable to a craft/yacht having the ✠**LMC** notation.

Periodical Survey Regulations for Service Craft

■ *Section 1* General

1.1 Frequency of surveys

1.1.1 The requirements of this Chapter are applicable to the Periodical Surveys set out in Ch 2,4.5. Except as amended at the discretion of the Committee, the periods between such surveys are as follows:

(a) Annual Surveys, as required by Ch 2,4.5.3.
(b) Intermediate Surveys as required by Ch 2,4.5.4.
(c) Docking Surveys as required by Ch 2,4.5.6 and 4.5.7.
(d) Special Surveys at five-yearly intervals, *see* Ch 2,4.5.11. For alternative arrangements, *see also* Ch 2,4.5.12, 4.5.13 and 4.5.15.
(e) Complete Surveys of machinery at five-yearly intervals, *see* Ch 2,4.5.16. For alternative arrangements, *see also* Ch 2,4.5.17, 4.5.19, 4.5.21, 4.5.22 and 4.5.23.

1.1.2 When it has been agreed that the complete survey of the hull and machinery may be carried out on the Continuous Survey basis, all compartments of the hull and all items of machinery are to opened for survey in rotation to ensure that the interval between consecutive examinations of each part will not exceed five years, *see* Ch 2,4.5.15 and 4.5.19.

1.1.3 For the frequency of surveys of screwshafts, tube shafts propellers and water jet units, *see* Section 11.

1.2 Surveys for damage or alterations

1.2.1 At any time when a craft is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g. if any part of the main or auxiliary machinery is removed for any reason, the hull structure in way is to be carefully examined by the Surveyor, or when cement in the bottom or sheathing on decks is removed, the structure in way is to be examined before the cement or sheathing is relaid.

1.3 Unscheduled surveys

1.3.1 In the event that Lloyd's Register (hereinafter referred to 'LR') has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull or machinery.

1.3.2 In the event of significant damage or defect affecting any craft, LR reserves the right to perform unscheduled surveys of the hull or machinery of other similar craft classed by LR and deemed to be vulnerable.

1.4 Surveys for the issue of Convention certificates

1.4.1 Surveys are to be held by LR when so appointed, or by the Exclusive Surveyors to a National Administration or by an IACS Member when so authorized by the National Authority, or, in the case of Cargo Ship Safety Radio Certificates or Safety Management Certificates, by any organization authorized by the National Authority. In the case of dual classed craft, Convention Certificates may be issued by the other Society with which the craft is classed provided this is recognized in a formal Dual Class Agreement with LR and provided the other Society is also authorized by the National Authority.

1.5 Definitions

1.5.1 **A Ballast tank** is a tank which is used solely for salt water ballast. A tank which is used for both cargo and salt water ballast will be treated as a salt water ballast tank when substantial corrosion has been found in that tank.

1.5.2 **Spaces** are separate hull compartments including integral tanks.

1.5.3 **Suspect areas** are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include:

(a) For steel hulls, areas of substantial corrosion and/or fatigue cracking.
(b) For aluminium alloy hulls, areas of fatigue cracking and areas in the vicinity of bimetallic connections.
(c) For composite hulls, areas subject to impact damage.
(d) For high speed craft (as defined in Ch 2,2.2.7), areas of the bottom structure forward prone to slamming damage.

1.5.4 **Substantial corrosion** is wastage of individual steel or aluminium plates and stiffeners in excess of 75 per cent of allowable margins, but within acceptable limits.

1.5.5 **Protective coatings** for steel craft should usually be hard coatings. Other coating systems (e.g. soft coating) may be considered acceptable as alternatives provided they are applied and properly maintained in compliance with the manufacturer's specification.

1.5.6 **Coating condition** for steel craft is defined as follows:
GOOD condition with only minor spot rusting affecting not more than 20 per cent of areas under consideration.

■ *Section 2*
Annual Surveys – Hull and machinery requirements

2.1 General

2.1.1 Annual Surveys are to be held concurrently with any relevant statutory annual or other statutory surveys, wherever practicable.

2.1.2 At Annual Surveys, the Surveyor is to examine the hull and machinery, so far as necessary and practicable, in order to be satisfied as to their general condition.

2.2 Annual Surveys

2.2.1 The Surveyor is to be satisfied regarding:
(a) The efficient condition of hatchways on freeboard and superstructure decks, weather deck plating, ventilator coamings and air pipes, exposed casings, skylights, flush deck scuttles, deckhouses and companionways, superstructure bulkheads, side, bow and stern doors, windows and storm shutters, side scuttles and deadlights, chutes and other openings, together with all closing appliances and flame screens.
(b) The efficient operating condition of mechanically operated hatch covers including stowage, fit, securing, locking, sealing and operational testing of hydraulic power components, wires, chains, etc.
(c) The efficient condition of scuppers and sanitary discharges (so far as is practicable); valves on discharge lines (so far as is practicable) and their controls; guard rails and bulwarks; freeing ports, gangways and life-lines; fittings and appliances for timber deck cargoes.
(d) The efficient condition of bilge level detection and alarm systems on craft assigned a **UMS** notation.

2.2.2 Any cargo hatch covers and coamings together with any cargo doors or ramps which form part of the watertight integrity of the hull are to be examined to ensure that no alterations have been made to the approved arrangements.
(a) Mechanically operated cargo hatch covers or doors are to be tested for tightness and to confirm the satisfactory condition of securing and sealing arrangements; drainage channels; operating mechanisms; tracks and wheels.
(b) Cargo hatch covers of the portable type are to be examined to confirm that the covers and closing appliances are in a satisfactory condition.

2.2.3 The anchoring and mooring equipment including anchor warps or wire ropes is to be examined so far as is practicable.

2.2.4 The watertight doors in watertight bulkheads, their indicators and alarms are to be examined and operationally tested locally and where applicable remotely. Other watertight bulkhead penetrations, are to be examined so far as is practicable.

2.2.5 The Surveyor is to examine and test in operation all main and auxiliary steering arrangements including their associated equipment and control systems, and verify that log book entries have been made in accordance with statutory requirements where applicable.

2.2.6 Where applicable, the Surveyor is to be satisfied regarding the freeboard marks on the craft's side.

2.2.7 The Surveyor is to generally inspect the machinery spaces with particular attention being given to the propulsion system, auxiliary machinery and to the existence of any fire and explosion hazards. Where applicable, emergency escape routes are to be checked to ensure that they are free of obstruction.

2.2.8 The means of communication between the navigating bridge and the machinery control positions, as well as the bridge and the alternative steering position, if fitted, are to be tested.

2.2.9 The bilge pumping systems and bilge wells, including operation of extended spindles, self closing drain cocks and level alarms, where fitted, are to be examined so far as is practicable. Satisfactory operation of the bilge pumps, including any hand pumps, is to be proven.

2.2.10 The boilers, other pressure vessels and their appurtenances, including foundations, controls, high pressure and waste steam piping, and insulation and gauges, are to be generally examined. Surveyors should confirm that Periodical Surveys of boilers and other pressure vessels have been carried out as required by the Rules.

2.2.11 For boilers, the safety devices are to be tested, and the safety valves are to be operated using the relieving devices. For exhaust gas heated economisers/boilers, the safety valves are to be tested at sea by the Chief Engineer and details recorded in the log book.

2.2.12 The operation and maintenance records, repair history and feed water chemistry records of boilers are to be examined.

2.2.13 For other pressure vessels, the safety devices are to be examined.

2.2.14 The electrical equipment and cabling forming the main and emergency electrical installations are to be generally examined under operating conditions so far as is practicable. The satisfactory operation of the main and emergency sources of power and electrical services essential for safety in an emergency is to be verified; where the sources of power are automatically controlled they should be tested in the automatic mode. Bonding straps for the control of static electricity and earthing arrangements are to be examined where fitted.

2.2.15 For craft having **UMS** or **CCS** notation, a General Examination of automation equipment is to be carried out. Satisfactory operation of safety devices and control systems is to be verified.

2.2.16 For craft to which Pt 17, Ch 1 applies, the arrangements for fire protection, detection and extinction are to be examined and are to include the following items, as required to be fitted in accordance with the Rules:
(a) Verification, so far as is practicable, that no significant changes have been made to the arrangement of structural fire protection.
(b) Verification of the operation of manual and/or automatic doors where fitted.
(c) Verification that fire control plans are properly posted;
(d) Examination, so far as is possible, and testing as feasible, of the fire and/or smoke detection and alarm system(s).
(e) Examination of fire main system, and confirmation that each fire pump, including the emergency fire pump can be operated separately so that the required jets of water can be produced simultaneously from different hydrants.
(f) Verification that fire-hoses, nozzles, applicators and spanners are in good working condition and situated at their respective locations.
(g) Examination of fixed fire-fighting systems controls, piping, instructions and marking, checking for evidence of proper maintenance and servicing, including date of last systems tests.
(h) Verification that all portable and semi-portable fire-extinguishers are in their stowed positions, checking for evidence of proper maintenance and servicing, conducting random checks for evidence of discharged containers.
(j) Verification, so far as is practicable, that the remote control for stopping fans and machinery and shutting off fuel supplies in machinery spaces and, where fitted, the remote controls for stopping fans in accommodation spaces and the means of cutting off power to the galley are in good working order.
(k) Examination of the closing arrangements of ventilators, skylights and doorways where applicable.
(l) Verification that the fireman's outfits are complete and in good condition.
(m) Verification that gas installations for domestic purposes comply with the relevant statutory requirements.

2.2.17 For steel craft, the requirements of 3.2.2 and 5.4.2 regarding the survey of water ballast spaces, integral sanitary tanks and bilges are also to be complied with as applicable.

■ *Section 3*
Intermediate Surveys – Hull and machinery requirements

3.1 General

3.1.1 Intermediate Surveys are to be held concurrently with statutory annual or other relevant statutory surveys wherever practicable.

3.2 Intermediate Surveys

3.2.1 The requirements of Section 2 are to be complied with so far as applicable.

3.2.2 For steel craft a general examination of salt water ballast tanks, integral sanitary tanks and bilges is to be carried out as required below. If such inspections reveal no visible structural defects then the examination may be limited to a verification that the protective coating remains in GOOD condition as defined in 1.5.6. When considered necessary by the Surveyor thickness measurement of the structure is to be carried out. Where the protective coating is found to be other than in GOOD condition, and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary at Annual Surveys.
(a) For all craft over five years of age and up to 10 years of age, representative salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined. Where the protective coating is found to be other than in GOOD condition, as defined in 1.5.6, or other defects are found, the examination is to be extended to other spaces of the same type.
(b) For steel craft over 10 years of age all salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined.

3.2.3 For all craft over 10 years of age the anchors are to be partially lowered and raised using the windlass.

3.2.4 The electrical generating sets are to be examined under working conditions.

3.2.5 Representative internal spaces including fore and aft peak spaces, machinery spaces, bilges, etc., are to be generally examined. These spaces should include all suspect areas, *see* 1.5.3.

■ *Section 4*
Docking Surveys and In-water Surveys – Hull and machinery requirements

4.1 General

4.1.1 At Docking Surveys or In-water Surveys the Surveyor is to examine the craft and machinery, so far as necessary and practicable, in order to be satisfied as to the general condition.

4.2 Docking Surveys

4.2.1 Where a craft is in dry-dock or on a slipway it is to be placed on blocks of sufficient height and proper staging is to be erected as may be necessary, for the examination of the outside of the hull, rudder(s) and underwater fittings. The outside surface of the hull is to be cleaned as may be required by the Surveyor.

4.2.2 Attention is to be given to parts of the external hull structure particularly liable to structural deterioration from causes such as high stresses, chafing and lying on the ground, and to areas of structural discontinuity.

4.2.3 The following parts of the external hull structure are to be specially examined:

(a) For steel hulls attention is to be given to parts of the structure particularly liable to excessive corrosion and to any undue unfairness of the plating of the bottom. The coating system is to be examined and made good as necessary.

(b) For aluminium alloy hulls attention is to be given to areas adjacent to any bimetallic connections at skin fittings, etc.

(c) For composite hulls the gelcoat or other protective finish is to be examined for surface cracking, blistering or other damage which may impair the efficiency of the protection to the underlying laminate.

4.2.4 Where required by the Rules, the satisfactory condition of the cathodic protection is to be confirmed.

4.2.5 The clearances in the rudder bearings and pintles are to be measured. Where considered necessary by the Surveyor rudders are to be lifted for examination of the stock. The securing of rudder couplings and/or pintle fastenings is to be confirmed.

4.2.6 The sea connections and overboard discharge valves, their attachments to the hull and the gratings at the sea inlets are to be examined.

4.2.7 The propeller and fastenings are to be examined. The sternbush is to be examined as far as is practicable.

4.2.8 The clearance in the sternbush or the efficiency of the oil glands is to be ascertained. The clearance of any shaft bracket bearings is to be ascertained.

4.2.9 The inboard shaft seals or glands are to be examined. Where flexible sternglands are fitted, the satisfactory condition of the rubber hose and securing clips is to be confirmed.

4.2.10 Special attention is to be given to the hull in way of underwater fittings such as transverse thrusters, stabilisers, etc.

4.2.11 Where applicable, attention is to be given to the connection and/or intersection of the cross-deck structure to the hulls of multi hull craft.

4.2.12 Where water jet units are fitted, the impeller, hull ducting, grating, nozzle steering and reversing arrangements are to be examined as far as is practicable.

4.2.13 Where transom mounted propulsion units are fitted, the steering arrangements and any flexible transom seals are to be examined.

4.2.14 When chain cables are ranged, the anchors and cables are to be examined by the Surveyor, *see also* 5.3.7 and Table 3.5.1.

4.2.15 For SES craft any flexible skirts together with their attachment are to be examined.

4.2.16 For hydrofoil or foil assisted craft the attachment of foils is to be examined.

4.3 In-water Surveys

4.3.1 The Committee will accept an In-water Survey in lieu of the intermediate docking between Special Surveys required in a five year period on craft where an ***IWS** notation is assigned, *see* Ch 2,3.8.2.

4.3.2 The Committee may accept an In-water Survey in lieu of the intermediate docking between Special Surveys required in a five year period on craft where suitable protection is applied to the underwater portion of the hull. If requested, an ***IWS** class notation may be assigned on satisfactory completion of the survey, provided that the applicable requirements of the Rules are complied with, *see also* Ch 2, 3.8.2.

4.3.3 The In-water Survey is to provide the information normally obtained from the Docking Survey, so far as is practicable.

4.3.4 Proposals for In-water Surveys are to be submitted in advance of the survey being required so that satisfactory arrangements can be agreed with LR.

4.3.5 The In-water Survey is to be carried out at agreed geographical locations under the surveillance of a Surveyor to LR, with the craft in sheltered waters; the in-water visibility is to be good and the hull below the waterline is to be clean. The Surveyor is to be satisfied that the method of pictorial presentation is satisfactory. There is to be good two-way communication between the Surveyor and the diver.

4.3.6 Diving and In-water Survey operations are to be carried out by firms recognized by the Committee. Continued recognition by the Committee will be dependent on the standard of workmanship by the firm being maintained to the satisfaction of LR's Surveyors.

4.3.7 If the In-water Survey reveals damage or deterioration that requires early attention, the Surveyor may require that the craft be dry-docked in order that a fuller survey can be undertaken and the necessary work carried out.

4.3.8 Where a vessel has an ***IWS** notation, the condition of the high resistant paint is to be confirmed at each dry-docking in order that the ***IWS** notation can be maintained.

4.3.9 Some National Administrations may have requirements additional to those of 4.3.1 to 4.3.8.

■ *Section 5* Special Survey – General – Hull requirements

5.1 General

5.1.1 The survey is to be of sufficient extent to ensure that the hull and related equipment is in satisfactory condition and is fit for its intended purpose, subject to proper maintenance and operation and to Periodical Surveys being carried out as required by the Regulations.

5.1.2 The requirements of Section 2 are to be complied with so far as applicable.

5.1.3 A Docking Survey in accordance with the requirements of 4.2 is to be carried out as part of the Special Survey.

5.2 Preparation

5.2.1 The craft is to be prepared for survey in accordance with the requirements of Table 3.5.1. The preparation should be of sufficient extent to facilitate an examination to ascertain any excessive corrosion, erosion, deformation, fractures, damages and other structural deterioration.

5.2.2 Where, in accordance with Table 3.5.1, the craft is opened out by removal of linings, ceilings, cabin sole, etc., and defects are found, further opening out will be required in order that the Surveyor can confirm the full extent of the defects.

5.3 Examination and testing – General

5.3.1 All spaces within the hull and superstructure including integral tanks are to be examined (*see also* 5.4.1 for tank examinations on steel craft). Special attention is to be paid to any suspect areas, *see* 1.5.3.

5.3.2 Double bottom compartments, peak tanks and all other integral tanks are to be tested by a head sufficient to give the maximum pressure that can be experienced in service. Tanks may be tested afloat provided that their internal examination is also carried out afloat.

5.3.3 Where repairs are effected to the hull shell or bulkheads, any integral tanks in way are to be tested to the Surveyor's satisfaction on completion of these repairs.

5.3.4 All decks, casings and superstructures are to be examined.

5.3.5 The satisfactory attachment of any wood or other deck sheathing is to be confirmed, *see also* 5.4.4.

Table 3.5.1 Survey preparation

Special Survey I (Craft 5 years old)	Special Survey II (Craft 10 years old)	Special Survey III (Craft 15 years old) and subsequent special surveys
(1) The interior of the craft is to be sufficiently opened out by the removal of lining, ceiling/cabin sole, portable tanks and ballast, etc as required in order that the Surveyor may be satisfied as to the condition of suspect areas of the structure, *see* 1.5.3. A record is to be made of those areas where lining, ceiling/cabin sole etc., were opened out and where equipment was removed during the survey. This record is to be retained for reference during subsequent surveys. (2) Machinery compartments, fore and aft peaks and other spaces as directed by the Surveyor, are to be cleared and cleaned as necessary, and the bilges and limbers all fore and aft are to be cleaned and prepared for examination. Platform plates in engine spaces are to be lifted as may be necessary for the examination of the structure below. Where necessary, pipework may be required to be removed for examination of the structure. (3) In way of the single and/or double bottom areas, a sufficient amount of ceiling/cabin sole is to be lifted to permit examination of the bilges and/or tanktops below. (4) All integral tanks are to be cleaned as necessary to permit examination. (For steel craft, *see* Table 3.5.2).	In addition to the requirements for Special Survey I, the following are to be complied with: (1) The chain locker is to be cleared and cleaned internally for examination of the structure and examination of the cable securing arrangements. The chain cables/anchor warps, as applicable, are to be ranged for inspection. The anchors are to be cleaned and placed in an accessible position for inspection. (2) The rudder is to be unshipped for examination of the rudder stock and trunk at the discretion of the Surveyor.	In addition to the requirements for Special Survey II the following are to be complied with: (1) Linings, ceiling/cabin soles, etc are to be removed as required in order that the Surveyor may be satisfied as to the condition of the structure. For steel craft: (2) Portions of wood sheathing, or other covering, on steel decks are to be removed, as considered necessary by the Surveyor, in order to ascertain the condition of the plating. (3) Where spaces are insulated, sufficient insulation is to be removed in each space to enable the Surveyors to be satisfied with the condition of the structure. (4) Linings are to be removed in way of shell plating immediately above tank top connections to the side shell, in way of galleys/washrooms and beneath portlights and windows.

5.3.6 Attention is to be given to the corners of openings and other discontinuities in the hull structure.

5.3.7 The anchors are to be examined. If the chain cables are ranged they are to be examined together with the chain locker, *see* Table 3.5.1. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 12 per cent or more from its nominal diameter, it is to be renewed. The windlass is to be examined.

5.3.8 The Surveyor is to be satisfied that there are suitable towlines and mooring ropes when these are a Rule requirement.

5.3.9 Representative structural fastenings, e.g. bolts in way of resiliently mounted deckhouses, are to be tested to ascertain their soundness and may require to be drawn for examination at the discretion of the Surveyor.

5.3.10 For craft to which Pt 17, Ch 1 applies, the Surveyor is to be satisfied as to the efficient condition of the means of escape from crew and passenger spaces, and spaces in which crew are normally employed.

5.4 Examination and testing – Additional items for steel craft

5.4.1 All integral tanks are generally to be internally examined. However, in certain circumstances the internal examination of lubricating oil, fresh water and oil fuel tanks may be waived. For the minimum extent of tank internal examination, *see* Table 3.5.2.

5.4.2 In salt water ballast spaces, integral sanitary tanks and bilges where the protective coating is found to be other than in GOOD condition as defined in 1.5.6 and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary at Annual Surveys.

5.4.3 The protection of steelwork, other than as referred to in 5.4.2 should be examined and made good where necessary on satisfactory completion of the survey. In areas where the inner surface of the bottom plating is covered with cement, asphalt or other composition, the removal of this covering may be dispensed with, provided that it is found sound and adhering satisfactorily to the steel.

5.4.4 Wood deck sheathing is to be examined and the caulking is to be tested and recaulked as necessary. If decay or rot is found, or the wood is excessively worn, the wood is to be renewed. Attention is to be given to the condition of the plating under wood deck sheathing or other deck covering. If it is found that such coverings are broken, or are not adhering closely to the plating, sections are to be removed as necessary to ascertain the condition of the plating. *See also* 1.2.1.

5.4.5 The structure in way of bimetallic connections, e.g. to aluminium alloy deckhouses is to be examined.

5.4.6 The Surveyors may require to measure the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality. The minimum requirements for thickness measurements are given in Section 6.

Table 3.5.2 Tank internal examination requirements for steel craft

Tank	Special Survey I (Craft 5 years old)	Special Survey II (Craft 10 years old)	Special Survey III (Craft 15 years old)	Special Survey IV (Craft 20 years old)	All Subsequent Special Surveys
Peaks	All tanks	All tanks	All tanks	All tanks	All tanks
Salt water ballast	All tanks	All tanks	All tanks	All tanks	All tanks
Lubricating oil	None	None	*See* Note 2	*See* Note 3	All tanks
Fresh water	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks
Oil fuel	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks
Sanitary	All tanks	All tanks	All tanks	All tanks	All tanks

NOTES
1. Tanks (excluding peak tanks) used exclusively for oil fuel or fresh water need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of the after end of one forward double bottom tank, and of one selected deep tank.
2. Tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of one double bottom tank forward and one aft and one deep tank.
3. Tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from internal examination of a least one double bottom tank amidships, one forward and one aft and one deep tank.
4. When examining tanks internally the Surveyor is to verify that striking plates or other additional reinforcement is fitted under sounding pipes. In the case of tanks fitted only with remote gauging facilities, the satisfactory operation of the gauges is to be confirmed.

5.5 Examination and testing – Additional items for aluminium alloy craft

5.5.1 The structure in way of any bimetallic connections is to be examined and the efficiency of the insulation arrangements confirmed.

5.5.2 The Surveyor may require to measure the thickness of the material in any portion of the structure where signs of deterioration are evident or may normally be found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality.

5.6 Examination and testing – Additional items for composite craft

5.6.1 The bonded attachments of frames, floors, bulkheads, structural joinery, engine bearers, sterntubes, rudder tubes, and integral tank boundaries are to be examined.

5.6.2 The hull to deck joint together with any joints between the deck and deckhouses or superstructures are to be examined.

5.6.3 The structure in way of the bolted attachment of fittings including guardrail stanchions, windlass, shaft brackets, fendering, mooring bitts, etc. is to be examined.

■ *Section 6*
Special Survey – Thickness measurement requirements for steel craft

6.1 General

6.1.1 Thickness measurements, as required by Section 5 are to be carried out in accordance with the following requirements.

6.1.2 Thickness measurements are to be taken at the forward and aft areas of all plates. In all cases the measurements are to represent the average of the multiple measurements taken on each plate. The extent of local substantial corrosion of plates is to be established by intensive measurement in the affected areas. Where measured plates are renewed, the thicknesses of adjacent plates in the same strake are to be reported.

6.1.3 Thickness measurements are normally to be by means of ultrasonic test equipment and are to be carried out by a firm qualified as Grade 1 or Grade 2 according to LR Approval for Thickness Measurement of Hull Structures or by the Surveyor.

6.1.4 The degree of supervision or check testing by the Surveyor is dependent upon the grade of approval extended to the firm carrying out the thickness measurements.

(a) The work of firms having Grade 1 approval is subject to check testing by the Surveyor.

(b) Thickness measurements by firms having Grade 2 approval is to be carried out with the Surveyor substantially in attendance.

6.1.5 Thickness measurements may be carried out in association with the fourth Annual Survey.

6.1.6 The minimum requirements for thickness measurement are indicated in Table 3.6.1.

6.1.7 The Surveyor may extend the scope of thickness measurement if deemed necessary.

6.2 Thickness measurement reporting

6.2.1 A report is to be prepared by the approved firm carrying out the thickness measurement. The report is to give the location of measurement, the thickness measured as well as the corresponding original thickness. The report is to give the date when the measurement was carried out, the type of measuring equipment, names of personnel and their qualifications and is to be signed by the operator and supervisor.

6.2.2 The thickness measurement report is to be verified and signed by the Surveyor.

Table 3.6.1 Thickness measurement of steel craft

Special Survey I (Craft 5 years old)	Special Survey II (Craft 10 years old)	Special Survey III (Craft 15 years old) (Craft 20 years old and over)	Special Survey IV and subsequent
Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	(1) Any exposed plating throughout the Main Deck. (2) Shell plating in way of the waterline throughout the length of the craft. (3) Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	(1) All Main Deck plating outside deckhouses or superstructures and including plating in way of wood deck planking or sheathing. (2) Shell plating in way of, and below, the waterline throughout the length of the craft. (3) 2 transverse sections of deck and shell plating within 0,5*L* amidships. (4) Suspect areas, as required by the Surveyor and to include as applicable: (a) Areas where the coatings are found to be other than in GOOD condition. (b) Shell and tanktop plating immediately adjacent to tank top margins. (c) Bottom shell in way of any cement, asphalt or other composition. (d) Shell plating below portlights and windows. (e) Tanktop plating below ceiling or cabin soles. (f) Deck plating and side shell plating in way of galleys, washrooms and refrigerated store spaces. (g) Structure in way of integral sanitary tanks.

NOTES
1. Suspect areas are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include, for steel hulls, areas of substantial corrosion and/or fatigue cracking, *see also* 1.5.3 and 5.4.6.
2. Coating condition for steel craft is defined in 1.5.6.

■ *Section 7* Machinery surveys – General requirements

7.1 Annual, Intermediate and Docking Surveys

7.1.1 For Annual, Intermediate and Docking Surveys, *see* Sections 2, 3 and 4.

7.1.2 For craft where an Approved Planned Maintenance Scheme is in operation an Annual Survey of the machinery is to be carried out together with an audit of the maintenance and monitoring records.

7.2 Complete Surveys

7.2.1 While the craft is in dry-dock, all openings to the sea in the machinery spaces and pump-rooms, together with the valves, cocks and the fastenings with which these are connected to the hull, are to be examined.

7.2.2 Athwartships thrust propellers are to be generally examined so far as is possible in dry dock and tested under working conditions afloat for satisfactory operation.

7.2.3 All shafts (except screwshafts and tube shafts, for which special arrangements are detailed in Section 11), thrust block and all bearings are to be examined. The lower halves of bearings need not be exposed if alignment and wear are found to be acceptable.

7.2.4 An examination is to be made as far as practicable of all propulsion gears complete with all wheels, pinions, shafts, bearings and gear teeth, thrust bearings and incorporated clutch arrangements.

7.2.5 The following auxiliaries and components are also to be examined:

(a) Auxiliary engines, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.
(b) Steering machinery.
(c) Windlass and associated driving equipment, where fitted.
(d) The holding down bolts, chocks or resilient mounts of main and auxiliary engines, gearcases, thrust blocks and intermediate shaft bearings.

7.2.6 All air receivers for essential services, together with their mountings, valves and safety devices, are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1,3 times the working pressure.

7.2.7 The valves, cocks and strainers of the bilge system including bilge injection, are to be opened up as considered necessary by the Surveyor and together with pipes, are to be examined and tested under working conditions. The oil fuel, feed, lubricating oil and cooling water systems also any ballast connections together with all pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

7.2.8 Fuel tanks which do not form part of the craft's structure are to be examined, and if considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally at the first survey if they are found satisfactory on external inspection. The mountings, fittings and remote controls of all oil fuel tanks are to be examined, so far as is practicable.

7.2.9 Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to demonstrate that they are in good working order.

7.2.10 In addition to the above, detailed requirements for gas turbines and oil engines and electrical installations are given in Sections 8, 9 and 10 respectively. In certain instances, upon application by the Owner or where indicated by the maker's servicing recommendations, the Committee will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking account of design, appropriate indicating equipment (e.g. vibration indicators) and operational records, *see* Ch 2,4.5.17 and 4.5.23.

■ *Section 8*
Gas turbines – Detailed requirements

8.1 Complete Surveys

8.1.1 The requirements of Section 7 are to be complied with. *See* 7.2.10 regarding any deviation from the following.

8.1.2 The following parts are to be opened out and examined:

- Compressor including impellers or blading, rotors and casing.
- Combustion chambers, burners, intercoolers and heat exchangers.
- Gas, air and fuel piping and fittings.
- Gas generator turbine and power turbine blading, rotors and casing.
- Rotors to include couplings, clutches, bearings and tie bolts.
- Auxiliary mounted fuel, L.O. and cooling water pumps, their drive transmissions and fittings.
- Starting system (for starting air pipes, *see* 9.1.3).
- All safety devices and local controls.
- Mountings and support frame.

8.1.3 The compressor/turbine units are to be operated and maintained in accordance with the manufacturer's instructions. Overhauls, including the prescribed replacement of limited life components, are to be undertaken at the specified intervals. Full service records are to be available for review by the Surveyor.

8.1.4 The manoeuvring of the propulsion system is to be tested under working conditions.

■ *Section 9*
Oil engines – Detailed requirements

9.1 Complete Surveys

9.1.1 The requirements of Section 7 are to be complied with. *See* 7.2.10 regarding any deviation from the following.

9.1.2 The following parts are to be opened out and examined:

- Cylinders and covers.
- Valves and valve gear.
- Pistons and connecting rods.
- Crankshafts and all bearings.
- Crankcases and entablatures.
- Crankcase door fastenings and explosion relief devices.
- Turbo-chargers and their associated coolers.
- Air compressors and their intercoolers.
- Filters and/or separators and safety devices.
- Fuel pumps and fittings.
- Camshaft drives and balancer units.
- Vibration dampers or detuners.
- Flexible couplings and clutches.
- Reverse gears.
- Attached pumps and cooling arrangements.

9.1.3 Selected pipes in the starting air system, if fitted, are to be removed for internal examination and are to be hammer tested. If any appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming out, or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors.

9.1.4 The electric ignition system, if fitted, is to be examined and tested.

9.1.5 The manoeuvring of engines is to be tested under working conditions. Initial starting arrangements are to be tested.

■ *Section 10* Electrical equipment

10.1 Annual and Intermediate Surveys

10.1.1 The requirements of 2.2.14 and 3.2.4 are to be complied with as far as applicable.

10.2 Complete Surveys

10.2.1 An electrical insulation resistance test is to be made on the electrical equipment and cables. The installation may be sub-divided, or equipment which may be damaged disconnected, for the purpose of this test.

10.2.2 The fittings on the main and emergency switchboards, section boards and distribution boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

10.2.3 Generator circuit-breakers are to be tested, so far as is practicable, to verify that protective devices including preference tripping relays, if fitted, operate satisfactorily.

10.2.4 The electric cables and their securing arrangements are to be examined, so far as is practicable, without undue disturbance of fixtures or casings unless opening up is considered necessary as a result of observation or of the tests required by 10.2.1.

10.2.5 The generator prime movers are to be surveyed as required by Sections 8 and 9 and the governing of the engines tested. The motors concerned with essential services together with associated control and switch gear are to be examined and if considered necessary, are to be operated, so far as is practicable, under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.

10.2.6 Where transformers or electrical apparatus associated with supplies to essential services are liquid filled or cooled by a liquid in direct contact with current carrying parts, the owner is to arrange for samples of the liquid to be taken and tested, by a competent authority, in accordance with the equipment manufacturer's requirements, and a certificate giving the test results is to be furnished to the Surveyor.

10.2.7 Navigation light indicators are to be tried under working conditions, and correct operation on the failure of supply or failure of navigation lights verified.

10.2.8 The emergency sources of electrical power, where fitted, together with their automatic arrangements and associated circuits are to be tested.

10.2.9 Emergency lighting, transitional emergency lighting, supplementary emergency lighting, general emergency alarm and public address systems are to be tested as far as practicable.

10.2.10 Where the craft is electrically propelled, the propulsion motors, generators, cables and all ancillary electrical gear, exciters and ventilating plant (including coolers) associated therewith are to be examined, and the insulation resistance to earth is to be tested. Special attention is to be given to windings, commutators and slip-rings. The operation of protective gear and alarm devices is to be checked, so far as is practicable. Liquids for filling and cooling, if used, are to be tested in accordance with 10.2.6. Interlocks intended to prevent unsafe operations or unauthorized access are to be checked to verify that they are functioning correctly. Emergency overspeed governors are to be tested.

10.2.11 Where batteries provide the source of power for any essential services, their installation, including charging and ventilation arrangements, is to be examined.

■ *Section 11* Screwshafts, tube shafts, propellers and water jet units

11.1 Frequency of surveys

11.1.1 Shafts with keyed propeller attachments and fitted with continuous liners or approved oil glands, or made of approved corrosion resistant materials, are to be surveyed at intervals of five years when the keyway complies fully with the present Rules.

11.1.2 Shafts having keyless type propeller attachments are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

11.1.3 Shafts having solid coupling flanges at the after end are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

11.1.4 All other shafts not covered by 11.1.1 to 11.1.3 are to be surveyed at intervals of $2^1/_2$ years.

11.1.5 Controllable pitch propellers for main propulsion purposes are to be surveyed at the same intervals as the screwshaft.

11.1.6 Directional propeller units for main propulsion purposes are to be surveyed at intervals not exceeding five years.

11.1.7 Water jet units for main propulsion purposes are to be surveyed at intervals not exceeding five years provided the impeller shafts are made of approved corrosion resistant material or have approved equivalent arrangements.

11.1.8 Athwartship thrust propellers and shaftings are to be surveyed at intervals not exceeding five years, *see* 7.2.2.

11.2 Normal surveys

11.2.1 All screwshafts are to be withdrawn for examination by LR's Surveyors at the intervals prescribed in 11.1.1 to 11.1.4. The after end of the cylindrical part of the shaft and forward one third of the shaft cone, or fillet of the flange, is to be examined by a magnetic particle crack detection method. In the case of a keyed propeller attachment at least the forward one third of the shaft cone is to be examined with the key removed. Weardown is to be measured and the sterntube bearings, oil glands, propellers and fastenings are to be examined. Controllable pitch propellers where fitted are to be opened up and the working parts examined, together with the control gear.

11.2.2 Directional propeller units are to be dismantled for examination of the propellers, shafts, gearing and control gear.

11.2.3 Water Jet Units are to be dismantled for examination of the impeller, casing, shaft, shaft seal, shaft bearing, inlet and outlets channels, steering nozzle, reversing arrangements, and control gear.

11.3 Screwshaft Condition Monitoring (SCM)

11.3.1 Where oil lubricated shafts with approved oil glands are fitted, and the Owner has complied with the following requirements, the descriptive note **SCM** (Screwshaft Condition Monitoring) may be entered in column 6 of the *Register Book*:

(a) Lubricating oil analysis to be carried out regularly at intervals not exceeding six months. The lubricating oil analysis documentation is to be available on board. Each analysis is to include the following minimum parameters:
  - water content
  - chloride content
  - bearing material and metal particles content
  - oil ageing (resistance to oxidation).

(b) Oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube.

(c) Oil consumption is to be recorded.

(d) Bearing temperatures are to be recorded (two temperature sensors or other approved arrangements are to be provided).

(e) Facilities are to be provided for measurement of bearing weardown.

(f) Oil glands are to be capable of being replaced without withdrawal of the screwshaft.

11.3.2 For maintenance of the descriptive note **SCM**, the records of analyses, consumption and temperatures, together with weardown readings, are to be retained on board and audited annually.

11.3.3 Where the requirements for the descriptive note **SCM** have been complied with, the screwshaft need not be withdrawn at surveys as required by 11.2.1 provided all condition monitoring data is found to be within permissible limits and all exposed areas of the shaft are examined by a magnetic particle crack detection method. The remaining requirements of 11.2.1 are to be complied with. Where the Surveyor considers that the data presented is not entirely to his satisfaction the shaft will be required to be withdrawn in accordance with 11.2.1.

11.4 Modified Survey

11.4.1 A Modified Survey may be accepted at alternate five-yearly surveys for shafts described in 11.1.1 provided they are fitted with oil lubricated bearings and approved oil glands, and also for those in 11.1.2 and 11.1.3.

11.4.2 The Modified Survey is to consist of the partial withdrawal of the shaft, sufficient to ascertain the condition of the stern bearing and shaft in way. For keyless propellers or shafts with a solid flange connection to the propeller a visual examination to confirm the good condition of the sealing arrangements is to be made. The oil glands are to be capable of being replaced without removal of the propeller. The forward bearing and all accessible parts including the propeller connection to the shaft are to be examined as far as possible. Wear down is to be measured and found satisfactory. Where a controllable pitch propeller is fitted, at least one of the blades is to be dismantled complete for examination of the working parts and the control gear.

11.4.3 For keyed propellers, the after end of the cylindrical part of the shaft and forward one third of the shaft cone is to be examined by a magnetic particle crack detection method, for which dismantling of the propeller and removal of the key will be required.

11.4.4 Where the descriptive note **SCM** has been assigned as described in 11.3.1 and all data is found to be within permissible limits, partial withdrawal of the shaft may not be required. Where doubt exists regarding any of the above findings the shaft is to be withdrawn to permit an entire examination.

11.5 Partial Survey

11.5.1 For shafts where the Modified Survey is applicable, upon application by the Owner, the Committee will be prepared to give consideration to postponement of the survey for a maximum period of half the specified cycle provided a Partial Survey is held.

11.5.2 The Partial Survey is to consist of the propeller being backed off in any keyed shaft and the top half of the cone examined by an efficient crack detection method for which removal of the key will be required. Oil gland and seals are to be examined and dealt with as necessary. Weardown is to be measured and found satisfactory. Propeller and fastenings are to be examined.

11.5.3 The Committee will be prepared to give consideration to the circumstances of any special case upon application by the Owner.

■ *Section 12* Classification of craft not built under survey

12.1 General

12.1.1 When classification is desired for a craft not built under the supervision of LR's Surveyors, application should be made to the Committee in writing.

12.1.2 Periodical Surveys of such craft, when classed, are subsequently to be held as in the case of craft built under survey.

12.1.3 Where classification is desired for a craft which is classed by another recognized Society, special consideration will be given to the scope of the survey.

12.2 Hull and equipment

12.2.1 Plans showing the main scantlings and arrangements of the actual craft together with any proposed alterations are to be submitted for approval.These should comprise plans of the midship section, longitudinal section and decks, and such other plans as may be requested. If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the craft.

12.2.2 Particulars of the process of manufacture and the testing of the material of construction are to be supplied. The requirements for composite craft will be specially considered.

12.2.3 The full requirements of Sections 5 and 6 are to be carried out as applicable. Craft of recent construction will receive special consideration.

12.2.4 During the survey, the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements. For this purpose, and also in order to ascertain the amount of any deterioration of steel craft, parts of the structure will require to be gauged as necessary. Full particulars of the anchors, chain cables and equipment are to be submitted. For craft to which Pt 15, Ch 1 applies, fire protection, detection and extinction are to be in accordance with the Rules.

12.2.5 When the full survey requirements indicated in 12.2.3 and 12.2.4 cannot be completed at one time, the Committee may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merits of each particular case, which should be submitted for consideration.

12.3 Machinery

12.3.1 To facilitate the survey, the following plans and particulars (plans of piping are to be diagrammatic), together with the particulars of the materials used in the construction of any boilers, air receivers and important forgings are to be submitted:

- Name of manufacturer of engine and gearbox including the manufacturer's type designation of engine and gearbox, together with the continuous shaft power of the engine at the crankshaft coupling with the revolutions per minute of crankshaft and propeller.
- General pumping arrangements, including air and sounding pipes (Builder's plan).
- Bilge, ballast and oil fuel pumping arrangements including the capacities of the pumps on bilge service.
- Arrangement and dimensions of any steam pipes.
- Arrangement of oil fuel pipes and fittings at settling and service tanks.
- Arrangement of oil fuel piping in connection with oil burning installations.
- Oil fuel overflow systems, where these are fitted.
- Arrangement of boiler feed systems.
- Oil fuel settling, service and other oil fuel tanks not forming part of the craft's structure.
- Boilers and economizers.
- Air receivers.
- Crank, thrust, intermediate and screw shafting.
- Details of water jet or directional propeller units, if fitted.
- Clutch and reversing gear with methods of control.
- Reduction gearing.
- Propeller (including spare propeller if supplied) where the diameter exceeds 1m.
- Electrical circuits.
- Arrangement of compressed air systems for main and auxiliary services.
- Arrangement of lubricating oil, other flammable liquids and cooling water systems for main and auxiliary services.
- Steering gear including control arrangement.
- Arrangement of exhaust system indicating materials, method of cooling, and if water spray injected, the method of draining.

12.3.2 Plans additional to those detailed in 12.3.1 are not to be submitted unless the machinery is of a novel or special character affecting classification.

12.3.3 Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted.

12.3.4 For new craft and craft which have been in service less than two years, calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration, as required for craft constructed under Special Survey. For older craft the circumstances will be specially considered in relation to their service record and type of machinery installed. Where calculations are not submitted, the Committee may require that the machinery certificate be endorsed to this effect. When desired by the Owner, the calculations and investigation of the torsional vibration characteristics of the machinery may be carried out by LR upon special request.

12.3.5 The main and auxiliary machinery, feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys. Working pressures are to be determined from the actual scantlings in accordance with the Rules.

12.3.6 The screwshaft is to be drawn and examined.

12.3.7 Any steam pipes or oil burning installations are to be examined and tested as required by Pt 1, Ch 3,15 or Ch 3,16 of the Rules for Ships.

12.3.8 The bilge, ballast and oil fuel pumping arrangements are to be examined and amended, as necessary, to comply with the Rules.

12.3.9 The electrical equipment is to be examined as required at Complete Surveys.

12.3.10 The whole of the machinery, including essential controls, is to be tried under working conditions to the Surveyor's satisfaction.

Periodical Survey Regulations for Yachts

Section

■ *Section 1* General

1.1 Frequency of surveys

1.1.1 The requirements of this Chapter are applicable to the Periodical Surveys set out in Ch 2,4.5. Except as amended at the discretion of the Committee, the periods between such surveys are as follows:

(a) Intermediate Surveys as required by Ch 2,4.5.5.
(b) Docking Surveys as required by Ch 2,4.5.6 and 4.5.7.
(c) Special Surveys at five-yearly intervals, *see* Ch 2,4.5.11. For alternative arrangements, *see also* Ch 2,4.5.12, 4.5.13 and 4.5.15.
(d) Complete Surveys of machinery at five-yearly intervals, *see* Ch 2,4.5.16. For alternative arrangements, *see also* Ch 2,4.5.17, 4.5.19, 4.5.21, 4.5.22 and 4.5.23.

1.1.2 When it has been agreed that the Complete Survey of the hull and machinery may be carried out on the Continuous Survey basis, all compartments of the hull and all items of machinery are to be opened for survey in rotation to ensure that the interval between consecutive examinations of each part will not exceed five years, *see* Ch 2,4.5.15 and 4.5.19.

1.1.3 For the frequency of surveys of screwshafts, tube shafts, propellers and water jet units, *see* Section 10.

1.2 Surveys for damage or alterations

1.2.1 At any time when a yacht is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g. if any part of the main or auxiliary machinery is removed for any reason, the hull structure in way is to be carefully examined by the Surveyor, or when cement in the bottom or sheathing on decks is removed the structure in way is to be examined before the cement or sheathing is relaid.

1.3 Unscheduled surveys

1.3.1 In the event that Lloyd's Register (hereinafter referred to as 'LR') has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull or machinery.

1.3.2 In the event of significant damage or defect affecting any yacht, LR reserves the right to perform unscheduled surveys of the hull or machinery of other similar yachts classed by LR and deemed to be vulnerable.

1.4 Surveys for the issue of Convention certificates

1.4.1 Surveys are to be held by LR when so appointed, or by the Exclusive Surveyors to a National Administration or by an IACS Member when so authorized by the National Authority, or, in the case of Cargo Ship Safety Radio Certificates or Safety Management Certificates, by any organization authorized by the National Authority. In the case of dual classed yachts, Convention Certificates may be issued by the other Society with which the yacht is classed provided this is recognized in a formal Dual Class Agreement with LR and provided the other Society is also authorized by the National Authority.

1.5 Definitions

1.5.1 A **Ballast tank** is a tank which is used primarily for salt water ballast.

1.5.2 **Spaces** are separate hull compartments including integral tanks.

1.5.3 **Suspect areas** are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include:

(a) For steel hulls, areas of substantial corrosion and/or fatigue cracking.
(b) For aluminium alloy hulls, areas of fatigue cracking and areas in the vicinity of bimetallic connections.
(c) For composite hulls, areas subject to impact damage.
(d) For wood hulls, areas subject to decay as a result of fresh water ingress or poor ventilation.
(e) For high speed craft (as defined in Ch 2,2.2.7), areas of the bottom structure forward prone to slamming damage.
(f) For sailing craft, areas subject to high local stresses due to rigging loads and ballast keel attachments.

1.5.4 **Substantial corrosion** is wastage of individual steel or aluminium plates and stiffeners in excess of 75 per cent of allowable margins, but within acceptable limits.

1.5.5 **Protective coatings** for steel craft should usually be hard coatings. Other coating systems (e.g. soft coating) may be considered acceptable as alternatives provided they are applied and maintained in compliance with the manufacturer's specification.

1.5.6 **Coating condition** for steel yacht is defined as follows:

GOOD condition with only minor spot rusting affecting not more than 20 per cent of areas under consideration.

■ *Section 2*
Intermediate Surveys – Hull and machinery requirements

2.1 General

2.1.1 At Intermediate Surveys, the Surveyor is to examine the hull and machinery, so far as necessary and practicable, in order to be satisfied as to their general condition.

2.2 Intermediate Surveys

2.2.1 The Surveyor is to be satisfied regarding:

(a) The efficient condition of hatchways on freeboard and superstructure decks, weather deck plating, ventilator coamings and air pipes, exposed casings, skylights, flush deck scuttles, deckhouses and companionways, superstructure bulkheads, side, bow and stern doors, windows and storm shutters, side scuttles and deadlights, chutes and other openings, together with all closing appliances and flame screens.

(b) The efficient condition of scuppers and sanitary discharges (so far as is practicable); valves on discharge lines (so far as is practicable) and their controls; guard rails and bulwarks; freeing ports, gangways and life-lines.

(c) The efficient condition of bilge level detection and alarm systems on yachts assigned a **UMS** notation.

2.2.2 The anchoring and mooring equipment including anchor warps or wire ropes is to be examined so far as is practicable. For all yachts over 10 years of age the anchors are to be partially lowered and raised using the windlass.

2.2.3 The watertight doors in watertight bulkheads are to be examined and operationally tested locally and where applicable remotely. Other watertight bulkhead penetrations, are to be examined so far as is practicable.

2.2.4 The Surveyor is to examine and test in operation all main and auxiliary steering arrangements including their associated equipment and control systems.

2.2.5 The Surveyor is to generally inspect the machinery spaces with particular attention being given to the propulsion system, auxiliary machinery and to the existence of any fire and explosion hazards. Where applicable, emergency escape routes are to be checked to ensure that they are free of obstruction.

2.2.6 The means of communication between the navigating bridge and the machinery control positions, as well as the bridge and the alternative steering position, if fitted, are to be tested.

2.2.7 The bilge pumping systems and bilge wells, including operation of extended spindles, self closing drain cocks and level alarms, where fitted, are to be examined so far as is practicable. Satisfactory operation of the bilge pumps, including any hand pumps, is to be proven.

2.2.8 Any pressure vessels including safety devices, foundations, controls, relieving gear, associated piping systems, insulation and gauges, are to be generally examined. Surveyors should confirm that Periodical Surveys of pressure vessels have been carried out as required by the Rules and that the safety devices have been tested.

2.2.9 The electrical equipment and cabling forming the main and emergency electrical installations are to be generally examined under operating conditions so far as is practicable. The satisfactory operation of the main and emergency sources of power and electrical services essential for safety in an emergency is to be verified; where the sources of power are automatically controlled they should be tested in the automatic mode. Bonding straps for the control of static electricity and earthing arrangements are to be examined where fitted.

2.2.10 The electrical generating sets are to be examined under working conditions.

2.2.11 For yachts having **UMS** or **CCS** notation, a General Examination of automation equipment is to be carried out. Satisfactory operation of safety devices and control systems is to be verified.

2.2.12 For yachts to which Pt 17, Ch 1 applies, the arrangements for fire protection, detection and extinction are to be examined and are to include the following items, as required to be fitted in accordance with the Rules:

(a) Verification, so far as is practicable, that no significant changes have been made to the arrangement of structural fire protection.

(b) Verification of the operation of manual and/or automatic doors where fitted.

(c) Verification that fire control plans are properly posted.

(d) Examination, so far as is possible, and testing as feasible, of the fire and/or smoke detection and alarm system(s).

(e) Examination of fire main system, and confirmation that each fire pump, including the emergency fire pump can be operated separately so that the required jets of water can be produced simultaneously from different hydrants.

(f) Verification that fire-hoses, nozzles, applicators and spanners are in good working condition and situated at their respective locations.

(g) Examination of fixed fire-fighting systems controls, piping, instructions and marking, checking for evidence of proper maintenance and servicing, including date of last systems tests.
(h) Verification that all portable and semi-portable fire-extinguishers are in their stowed positions, checking for evidence of proper maintenance and servicing, conducting random checks for evidence of discharged containers.
(j) Verification, so far as is practicable, that the remote control for stopping fans and machinery and shutting off fuel supplies in machinery spaces and, where fitted, the remote controls for stopping fans in accommodation spaces and the means of cutting off power to the galley are in good working order.
(k) Examination of the closing arrangements of ventilators, skylights and doorways where applicable.
(l) Verification that the fireman's outfits are complete and in good condition.
(m) Verification that gas installations for domestic purposes comply with the relevant statutory requirements.

2.2.13 For steel yachts a general examination of salt-water ballast tanks, integral sanitary tanks and bilges is to be carried out as required below. If such inspections reveal no visible structural defects then the examination may be limited to a verification that the protective coating remains in GOOD condition as defined in 1.5.6. When considered necessary by the Surveyor thickness measurement of the structure is to be carried out. Where the protective coating is found to be other than in GOOD condition, and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary annually.
(a) For all yachts over five years of age and up to 10 years of age, representative salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined. Where the protective coating is found to be other than in GOOD condition, as defined in 1.5.6, or other defects are found, the examination is to be extended to other spaces of the same type.
(b) For steel yachts over 10 years of age all salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined.

2.2.14 Representative internal spaces including fore and aft peak spaces, machinery spaces, bilges, etc are to be generally examined. These spaces should include all suspect areas, *see* 1.5.3.

2.2.15 In sailing and auxiliary yachts, the mast(s), mast steps, spars, standing and running rigging, rigging screws, chainplates and sails are to be examined so far as is practicable.

■ *Section 3* Docking Surveys and In-water Surveys – Hull and machinery requirements

3.1 General

3.1.1 At Docking Surveys or In-water Surveys the Surveyor is to examine the yacht and machinery, so far as necessary and practicable, in order to be satisfied as to the general condition.

3.2 Docking Surveys

3.2.1 Where a yacht is in dry-dock or on a slipway it is to be placed on blocks of sufficient height and proper staging is to be erected as may be necessary, for the examination of the outside of the hull, rudder(s) and underwater fittings. The outside surface of the hull is to be cleaned as may be required by the Surveyor.

3.2.2 Attention is to be given to parts of the external hull structure particularly liable to structural deterioration from causes such as high stresses, chafing and lying on the ground, and to areas of structural discontinuity.

3.2.3 The following parts of the external hull structure are to be specially examined:
(a) For steel hulls attention is to be given to parts of the structure particularly liable to excessive corrosion and to any undue unfairness of the plating of the bottom. The coating system is to be examined and made good as necessary.
(b) For aluminium alloy hulls attention is to be given to areas adjacent to any bimetallic connections at skin fittings, etc.
(c) For composite hulls the gelcoat or other protective finish is to be examined for surface cracking, blistering or other damage which may impair the efficiency of the protection to the underlying laminate.
(d) For wood hulls the condition of any caulking or sheathing is to be examined as applicable. The condition of external fastenings may require to be confirmed by removal at the discretion of the Surveyor.
(e) For sailing or auxiliary yachts fitted with external ballast, the attachment of bilge or centreline ballast keels is to be examined.

3.2.4 Where required by the Rules, the satisfactory condition of the cathodic protection is to be confirmed.

3.2.5 The clearances in the rudder bearings and pintles are to be measured. Where considered necessary by the Surveyor rudders are to be lifted for examination of the stock. The securing of rudder couplings and/or pintle fastenings is to be confirmed.

3.2.6 The sea connections and overboard discharge valves, their attachments to the hull and the gratings at the sea inlets are to be examined.

3.2.7 The propeller and fastenings are to be examined. The sternbush is to be examined as far as is practicable.

3.2.8 The clearance in the sternbush or the efficiency of the oil gland is to be ascertained. The clearance of any shaft bracket bearings is to be ascertained.

3.2.9 The inboard shaft seals or glands are to be examined. Where flexible sternglands are fitted, the satisfactory condition of the rubber hose and securing clips is to be confirmed.

3.2.10 Special attention is to be given to the hull in way of underwater fittings such as transverse thrusters, stabilisers, etc.

3.2.11 Where applicable, attention is to be given to the connection and/or intersection of the cross-deck structure to the hulls of multi hull craft.

3.2.12 Where water jet units are fitted, the impeller, hull ducting, grating, nozzle steering and reversing arrangements are to be examined as far as is practicable.

3.2.13 Where transom mounted propulsion units are fitted, the steering arrangements and any flexible transom seals are to be examined.

3.2.14 When chain cables are ranged, the anchors and cables are to be examined by the Surveyor, *see also* 4.3.7 and Table 4.4.1.

3.3 In-water Surveys

3.3.1 The Committee will accept an In-water Survey in lieu of the intermediate docking between Special Surveys required in a five year period on yachts where an ***IWS** notation is assigned, *see* Ch 2,3.8.2.

3.3.2 The Committee may accept an In-water Survey in lieu of the intermediate docking between Special Surveys required in a five year period on yachts where suitable protection is applied to the underwater portion of the hull. If requested, an ***IWS** class notation may be assigned on satisfactory completion of the Survey, provided that the applicable requirements of the Rules are complied with, *see also* Ch 2,3.8.2.

3.3.3 The In-water Survey is to provide the information normally obtained from the Docking Survey, so far as is practicable.

3.3.4 Proposals for In-water Surveys are to be submitted in advance of the survey being required so that satisfactory arrangements can be agreed with LR.

3.3.5 The In-water Survey is to be carried out at agreed geographical locations under the surveillance of a Surveyor to LR, with the yacht in sheltered waters; the in-water visibility is to be good and the hull below the waterline is to be clean. The Surveyor is to be satisfied that the method of pictorial presentation is satisfactory. There is to be good two-way communication between the Surveyor and the diver.

3.3.6 Diving and In-water Survey operations are to be carried out by firms recognized by the Committee. Continued recognition by the Committee will be dependent on the standard of workmanship by the firm being maintained to the satisfaction of LR's Surveyors.

3.3.7 If the In-water Survey reveals damage or deterioration that requires early attention, the Surveyor may require that the yacht be dry-docked in order that a fuller survey can be undertaken and the necessary work carried out.

3.3.8 Where a yacht has an ***IWS** notation, the condition of the high resistant paint is to be confirmed at each dry-docking in order that the ***IWS** notation can be maintained.

3.3.9 Some National Administrations may have requirements additional to those of 3.3.1 to 3.3.8.

■ *Section 4* Special Survey – General – Hull requirements

4.1 General

4.1.1 The survey is to be of sufficient extent to ensure that the hull and related equipment is in satisfactory condition and is fit for its intended purpose, subject to proper maintenance and operation and to Periodical Surveys being carried out as required by the Regulations.

4.1.2 The requirements of Section 2 are to be complied with so far as applicable.

4.1.3 A Docking Survey in accordance with the requirements of 3.2 is to be carried out as part of the Special Survey.

4.1.4 For sailing and auxiliary yachts fitted with unclassed machinery installations the requirements of 11.3.1 are to be complied with.

4.2 Preparation

4.2.1 The yacht is to be prepared for survey in accordance with the requirements of Table 4.4.1. The preparation should be of sufficient extent to facilitate an examination to ascertain any excessive corrosion, erosion, deformation, fractures, damages and other structural deterioration.

4.2.2 Where, in accordance with Table 4.4.1, the yacht is opened out by removal of linings, cabin sole, etc., and defects are found, further opening out will be required in order that the Surveyor can confirm the full extent of the defects.

4.3 Examination and testing – General

4.3.1 All spaces within the hull and superstructure including integral tanks are to be examined (*see also* 4.4.1 for tank examinations on steel craft). Special attention is to be paid to any suspect areas, *see* 1.5.3.

Table 4.4.1 Survey preparation

Special Survey I (Yachts 5 years old)	Special Survey II (Yachts 10 years old)	Special Survey III (Yachts 15 years old) and subsequent special surveys
(1) The interior of the yacht is to be sufficiently opened out by the removal of lining, ceiling/cabin sole, portable tanks and ballast, etc as required in order that the Surveyor may be satisfied as to the condition of suspect areas of the structure (*see* 1.5.3). A record is to be made of those areas where lining, cabin sole, etc., were opened out and where equipment was removed during the survey. This record is to be retained for reference during subsequent surveys. (2) Machinery compartments, fore and aft peaks and other spaces as directed by the Surveyor, are to be cleared and cleaned as necessary, and the bilges and limbers all fore and aft are to be cleaned and prepared for examination. Platform plates in engine spaces are to be lifted as may be necessary for the examination of the structure below. Where necessary, pipework may be required to be removed for examination of the structure. (3) In way of the single and/or double bottom areas, a sufficient amount of cabin sole is to be lifted to permit examination of the bilges and/or tanktops below. (4) All integral tanks are to be cleaned as necessary to permit examination. (For steel yachts, *see* Table 4.4.2). (5) In sailing and auxiliary yachts the sails are to be laid out so that they can be properly examined.	In addition to the requirements for Special Survey I, the following are to be complied with: (1) The chain locker is to be cleared and cleaned internally for examination of the structure and examination of the cable securing arrangements. The chain cables/anchor warps, as applicable, are to be ranged for inspection. The anchors are to be cleaned and placed in an accessible position for inspection. (2) The rudder is to be unshipped for examination of the rudder stock and trunk at the discretion of the Surveyor. For sailing or auxiliary yachts: (3) On yachts fitted with an external ballast keel, fastenings are to be drawn for examination as may be required by the Surveyor. (4) On yachts fitted with a centreplate or lifting keel, the pivot bolts and lifting arrangements are to be dismantled for examination as required by the Surveyor. For wood yachts: (5) Where the hull is sheathed with metal, such sheathing as will permit an examination of the stem, wood keel, garboards, plank ends and sternpost is to be removed as required by the Surveyor. (6) Fastenings are to be drawn as may be required by the Surveyor. (7) The outside surface of the planking is to be scraped bright at the discretion of the Surveyor.	In addition to the requirements for Special Survey II the following are to be complied with: (1) Linings, ceiling/cabin soles, etc. are to be removed as required in order that the Surveyor may be satisfied as to the condition of the structure. For steel yachts: (2) Portions of wood sheathing, or other covering, on steel decks are to be removed, as considered necessary by the Surveyor, in order to ascertain the condition of the plating. (3) Where spaces are insulated, sufficient insulation is to be removed in each space to enable the Surveyors to be satisfied with the condition of the structure. (4) Linings are to be removed in way of shell plating immediately above tank top connections to the side shell, in way of galleys/washrooms and beneath portlights and windows. For sailing or auxiliary yachts: (5) The masts are to be unshipped for survey. The whole of the standing rigging, including rigging screws, bolts, pins and fittings, is to be dismantled as considered necessary by the Surveyor. NOTE This requirement may be waived at alternate Special Surveys provided the masts and rigging are thoroughly examined *in situ*. (6) On yachts fitted with an external ballast keel, a minimum of 50% of the total number of ballast keel fastenings are to be drawn for examination as required by the Surveyor. If defects are found the remaining fastenings should be drawn for sexamination. For wood yachts: (7) Where iron or mild steel fastenings are used, as a minimum requirement the following are to be drawn for examination where applicable: • 6 floor arm fastenings each side. • 4 hanging knee fastenings each side. • 4 chain plate fastenings each side at each mast. • 18 frame to plank fastenings each side. • 12 garboard and 12 plank end fastenings each side.

4.3.2 Double bottom compartments, peak tanks and all other integral tanks are to be tested by a head sufficient to give the maximum pressure that can be experienced in service. Tanks may be tested afloat provided that their internal examination is also carried out afloat.

4.3.3 Where repairs are effected to the hull shell or bulkheads, any integral tanks in way are to be tested to the Surveyor's satisfaction on completion of these repairs.

4.3.4 All decks, casings and superstructures are to be examined.

4.3.5 The satisfactory attachment of any wood or other deck sheathing is to be confirmed, *see also* 4.4.4.

4.3.6 Attention is to be given to the corners of openings and other discontinuities in the hull structure.

4.3.7 The anchors are to be examined. If the chain cables are ranged they are to be examined together with the chain locker, *see* Table 4.4.1. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 12 per cent or more from its nominal diameter, it is to be renewed. The windlass is to be examined.

4.3.8 The Surveyor is to be satisfied that there are suitable towlines and mooring ropes when these are a Rule requirement.

4.3.9 Representative structural fastenings, are to be tested to ascertain their soundness and may require to be drawn for examination at the discretion of the Surveyor.

4.3.10 For yachts to which Pt 17, Ch 1 applies, the Surveyor is to be satisfied as to the efficient condition of the means of escape from crew and passenger spaces, and spaces in which crew are normally employed.

4.4 Examination and testing – Additional items for steel yachts

4.4.1 All integral tanks are generally to be internally examined. However, in certain circumstances the internal examination of lubricating oil, fresh water and oil fuel tanks may be waived. For the minimum extent of tank internal examination, *see* Table 4.4.2.

4.4.2 In salt water ballast spaces, integral sanitary tanks and bilges, where the protective coating is found to be other than in GOOD condition as defined in 1.5.6 and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary annually.

4.4.3 The protection of steelwork, other than as referred to in 4.4.2 should be examined and made good where necessary on satisfactory completion of the survey. In areas where the inner surface of the bottom plating is covered with cement, asphalt or other composition, the removal of this covering may be dispensed with, provided that it is found sound and adhering satisfactorily to the steel.

4.4.4 Wood decks or sheathing are to be examined and the caulking is to be tested and recaulked as necessary. If decay or rot is found, or the wood is excessively worn, the wood is to be renewed. When a wood deck, laid on stringers and ties, has worn by 20 per cent or more in thickness, it is to be renewed. Attention is to be given to the condition of the plating under wood deck sheathing or other deck covering. If it is found that such coverings are broken, or are not adhering closely to the plating, sections are to be removed as necessary to ascertain the condition of the plating, *see also* 1.2.1.

4.4.5 The structure in way of bimetallic connections, e.g. to aluminium alloy deckhouses is to be examined.

Table 4.4.2 Tank internal examination requirements for steel yachts

Tank	Special Survey I (Yachts 5 years old)	Special Survey II (Yachts 10 years old)	Special Survey III (Yachts 15 years old)	Special Survey IV (Yachts 20 years old)	All Subsequent Special Surveys
Peaks	All tanks	All tanks	All tanks	All tanks	All tanks
Salt water ballast	All tanks	All tanks	All tanks	All tanks	All tanks
Lubricating oil	None	None	*See* Note 2	*See* Note 3	All tanks
Fresh water	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks
Oil fuel	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks
Sanitary	All tanks	All tanks	All tanks	All tanks	All tanks

NOTES
1. Tanks (excluding peak tanks) used exclusively for oil fuel or fresh water need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of the after end of one forward double bottom tank, and of one selected deep tank.
2. Tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of one double bottom tank forward and one aft and one deep tank.
3. Tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from internal examination of a least one double bottom tank amidships, one forward and one aft and one deep tank.
4. When examining tanks internally the Surveyor is to verify that striking plates or other additional reinforcement is fitted under sounding pipes. In the case of tanks fitted only with remote gauging facilities, the satisfactory operation of the gauges is to be confirmed.

4.4.6 The Surveyors may require to measure the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality. The minimum requirements for thickness measurements are given in Section 5.

4.5 Examination and testing – Additional items for aluminium alloy yachts

4.5.1 The structure in way of any bimetallic connections is to be examined and the efficiency of the insulation arrangements confirmed.

4.5.2 The Surveyor may require to measure the thickness of the material in any portion of the structure where signs of deterioration are evident or may normally be found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality.

4.6 Examination and testing – Additional items for composite yachts

4.6.1 The bonded attachments of frames, floors, bulkheads, structural joinery, engine bearers, sterntubes, rudder tubes, and integral tank boundaries are to be examined.

4.6.2 The hull to deck joint together with any joints between the deck and deckhouses or superstructures are to be examined.

4.6.3 The structure in way of the bolted attachment of fittings including guardrail stanchions, windlass, shaft brackets, fendering, mooring bitts, mast steps, rigging chainplates, etc., is to be examined.

4.7 Examination and testing – Additional items for wood yachts

4.7.1 Where hulls are provided with metal sheathing, the condition of the structure in way of any sheathing is to be confirmed. For the extent of removal of metal sheathing *see* Table 4.4.1. The satisfactory adhesion of any glass/nylon reinforced plastic sheathing is also to be confirmed.

4.7.2 Wood decks or sheathing are to be examined and the caulking is to be tested and re-caulked as necessary. If decay or rot is found or the wood has worn by 20 per cent or more in thickness, the wood is to be renewed. Attention is to be given to the condition of the structure under wood decks, and to fabric deck coverings. If it is found that such coverings are damaged or are not adhering closely to the deck, sections are to be removed as necessary to ascertain the condition of the deck under.

4.7.3 Fastenings as may be required by the Surveyor are to be drawn for examination, *see* Table 4.4.1.

4.8 Examination and testing – Additional items for sailing and auxiliary yachts

4.8.1 The mast(s), mast steps, spars, standing and running rigging, rigging screws, chainplates and sails are to be examined, *see* Table 4.4.1.

4.8.2 The structure in way of the attachment of bilge or centreline ballast keels is to be examined. Ballast keel bolts are to be tested to ascertain their soundness and may require to be drawn for examination, *see* Table 4.4.1.

4.8.3 On yachts fitted with a centreplate or lifting keel, the pivot bolt and lifting arrangements are to be examined as far as is practicable.

■ *Section 5* Special Survey – Thickness measurement requirements for steel yachts

5.1 General

5.1.1 Thickness measurements, as required by Section 4 are to be carried out in accordance with the following requirements.

5.1.2 Thickness measurements are to be taken at the forward and aft areas of all plates. In all cases the measurements are to represent the average of the multiple measurements taken on each plate. The extent of local substantial corrosion of plates is to be established by intensive measurement in the affected areas. Where measured plates are renewed, the thicknesses of adjacent plates in the same strake are to be reported.

5.1.3 Thickness measurements are normally to be by means of ultrasonic test equipment and are to be carried out by a firm qualified as Grade 1 or Grade 2 according to LR's *Approval for Thickness Measurement of Hull Structures* or by the Surveyor.

5.1.4 The degree of supervision or check testing by the Surveyor is dependent upon the grade of approval extended to the firm carrying out the thickness measurements:

(a) The work of firms having Grade 1 approval is subject to check testing by the Surveyor.
(b) Thickness measurements by firms having Grade 2 approval is to be carried out with the Surveyor substantially in attendance.

5.1.5 Thickness measurements may be carried out in association with the fourth Annual Survey.

5.1.6 The minimum requirements for thickness measurement are indicated in Table 4.5.1.

5.1.7 The Surveyor may extend the scope of thickness measurement if deemed necessary.

Table 4.5.1 Thickness measurement of steel yachts

Special Survey I (Yachts 5 years old)	Special Survey II (Yachts 10 years old)	Special Survey III (Yachts 15 years old)	Special Survey IV and subsequent (Yachts 20 years old and over)
Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	(1) Any exposed plating throughout the Main Deck. (2) Shell plating in way of the waterline throughout the length of the craft. (3) Suspect areas, as required by the Surveyor may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	(1) All Main Deck plating outside deckhouses or superstructures and including plating in way of wood deck planking or sheathing. (2) Shell plating in way of, and below, the waterline throughout the length of the craft. (3) 2 transverse sections of deck and shell plating within 0,5*L* amidships. (4) Suspect areas, as required by the Surveyor and to include as applicable: (a) Areas where the coatings are found to be other than in GOOD condition. (b) Shell and tanktop plating immediately adjacent to tank top margins. (c) Bottom shell in way of any cement, asphalt or other composition. (d) Shell plating below portlights and windows. (e) Tanktop plating below ceiling or cabin soles. (f) Deck plating and side shell plating in way of galleys, washrooms and refrigerated store spaces. (g) Structure in way of integral sanitary tanks.

NOTES
1. Suspect areas are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include, for steel hulls, areas of substantial corrosion and/or fatigue cracking, *see also* 1.5.3 and 4.4.6.
2. Coating condition for steel craft is defined in 1.5.6.

5.2 Thickness measurement reporting

5.2.1 A report is to be prepared by the approved firm carrying out the thickness measurement. The report is to give the location of measurement, the thickness measured as well as the corresponding original thickness. The report is to give the date when the measurement was carried out, the type of measuring equipment, names of personnel and their qualifications and is to be signed by the operator and supervisor.

5.2.2 The thickness measurement report is to be verified and signed by the Surveyor.

■ *Section 6*
Machinery surveys – General requirements

6.1 Intermediate and Docking Surveys

6.1.1 For Intermediate and Docking Surveys, *see* Sections 2 and 3.

6.1.2 For yachts where an Approved Planned Maintenance Scheme is in operation an Annual Survey of the machinery is to be carried out together with an audit of the maintenance and monitoring records.

6.2 Complete Surveys

6.2.1 While the yacht is in dry-dock, all openings to the sea in the machinery spaces and pump-rooms, together with the valves, cocks and the fastenings with which these are connected to the hull, are to be examined. For athwartships thrust propellers, *see* 10.1.8.

6.2.2 Athwartships thrust propellers are to be generally examined as far as is possible in dry dock and tested under working conditions afloat for satisfactory operation.

6.2.3 All shafts (except screwshafts and tube shafts, for which special arrangements are detailed in Section 10), thrust block and all bearings are to be examined. The lower halves of bearings need not be exposed if alignment and wear are found to be acceptable.

6.2.4 An examination is to be made as far as practicable of all propulsion gears complete with all wheels, pinions, shafts, bearings and gear teeth, thrust bearings and incorporated clutch arrangements.

6.2.5 The following auxiliaries and components are also to be examined:

(a) Auxiliary engines, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.
(b) Steering machinery.
(c) Windlass and associated driving equipment, where fitted.
(d) The holding down bolts, chocks or resilient mounts of main and auxiliary engines, gearcases, thrust blocks and intermediate shaft bearings.

6.2.6 All air receivers for essential services, together with their mountings, valves and safety devices, are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1,3 times the working pressure.

6.2.7 The valves, cocks and strainers of the bilge system including bilge injection, are to be opened up as considered necessary by the Surveyor and together with pipes, are to be examined and tested under working conditions. The oil fuel, feed, lubricating oil and cooling water systems also any ballast connections together with all pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

6.2.8 Fuel tanks which do not form part of the yacht's structure are to be examined, and if considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally at the first survey if they are found satisfactory on external inspection. The mountings, fittings and remote controls of all oil fuel tanks are to be examined, so far as is practicable.

6.2.9 Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to demonstrate that they are in good working order.

6.2.10 In addition to the above, detailed requirements for gas turbines and oil engines and electrical installations are given in Sections 7, 8 and 9 respectively. In certain instances, upon application by the Owner or where indicated by the maker's servicing recommendations, the Committee will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking account of design, appropriate indicating equipment (e.g. vibration indicators) and operational records, *see* Ch 2,4.5.17 and 4.5.23.

■ *Section 7* Gas turbines – Detailed requirements

7.1 Complete Surveys

7.1.1 The requirements of Section 6 are to be complied with. *See* 6.2.10 regarding any deviation from the following.

7.1.2 The following parts are to be opened out and examined:

- Compressor including impellers or blading, rotors and casing.
- Combustion chambers, burners, intercoolers and heat exchangers.
- Gas, air and fuel piping and fittings.
- Gas generator turbine and power turbine blading, rotors and casing.
- Rotors to include couplings, clutches, bearings and tie bolts.
- Auxiliary mounted fuel, L.O. and cooling water pumps, their drive transmissions and fittings.
- Starting system (for starting air pipes, *see* 8.1.3).
- All safety devices and local controls.
- Mountings and support frame.

7.1.3 The compressor/turbine units are to be operated and maintained in accordance with the manufacturer's instructions. Overhauls, including the prescribed replacement of limited life components, are to be undertaken at the specified intervals. Full service records are to be available for review by the Surveyor.

7.1.4 The manoeuvring of the propulsion system is to be tested under working conditions.

■ *Section 8* Oil engines – Detailed requirements

8.1 Complete Surveys

8.1.1 The requirements of Section 6 are to be complied with. *See* 6.2.10 regarding any deviation from the following.

8.1.2 The following parts are to be opened out and examined:

- Cylinders and covers.
- Valves and valve gear.
- Pistons and connecting rods.
- Crankshafts and all bearings
- Crankcases and entablatures.
- Crankcase door fastenings and explosion relief devices.
- Turbo-chargers and their associated coolers.
- Air compressors and their intercoolers.
- Filters and/or separators and safety devices.
- Fuel pumps and fittings.
- Camshaft drives and balancer units.
- Vibration dampers or detuners.
- Flexible couplings and clutches.
- Reverse gears.
- Attached pumps and cooling arrangements.

8.1.3 Selected pipes in the starting air system, if fitted, are to be removed for internal examination and are to be hammer tested. If any appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming out, or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors.

8.1.4 The electric ignition system, if fitted, is to be examined and tested.

8.1.5 The manoeuvring of engines is to be tested under working conditions. Initial starting arrangements are to be tested.

■ *Section 9*
Electrical equipment

9.1 Intermediate Surveys

9.1.1 The requirements of 2.2.9 and 2.2.13 are to be complied with as far as applicable.

9.2 Complete Surveys

9.2.1 An electrical insulation resistance test is to be made on the electrical equipment and cables. The installation may be sub-divided or equipment, which may be damaged, disconnected for the purpose of this test.

9.2.2 The fittings on the main and emergency switchboards, section boards and distribution boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

9.2.3 Generator circuit-breakers are to be tested, so far as is practicable, to verify that protective devices including preference tripping relays, if fitted, operate satisfactorily.

9.2.4 The electric cables and their securing arrangements are to be examined, so far as is practicable, without undue disturbance of fixtures or casings unless opening up is considered necessary as a result of observation or of the tests required by 9.2.1.

9.2.5 The generator prime movers are to be surveyed as required by Sections 7 and 8 and the governing of the engines tested. The motors concerned with essential services together with associated control and switch gear are to be examined and if considered necessary, are to be operated, so far as is practicable, under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.

9.2.6 Where transformers or electrical apparatus associated with supplies to essential services are liquid filled or cooled by a liquid in direct contact with current carrying parts, the owner is to arrange for samples of the liquid to be taken and tested, by a competent authority, in accordance with the equipment manufacturer's requirements, and a certificate giving the test results is to be furnished to the Surveyor.

9.2.7 Navigation light indicators are to be tried under working conditions, and correct operation on the failure of supply or failure of navigation lights verified.

9.2.8 The emergency sources of electrical power, where fitted, together with their automatic arrangements and associated circuits are to be tested.

9.2.9 Emergency lighting, transitional emergency lighting, supplementary emergency lighting, general emergency alarm and public address systems are to be tested as far as practicable.

9.2.10 Where the yacht is electrically propelled, the propulsion motors, generators, cables and all ancillary electrical gear, exciters and ventilating plant (including coolers) associated therewith are to be examined, and the insulation resistance to earth is to be tested. Special attention is to be given to windings, commutators and slip-rings. The operation of protective gear and alarm devices is to be checked, so far as is practicable. Liquids for filling and cooling, if used, are to be tested in accordance with 9.2.6. Interlocks intended to prevent unsafe operations or unauthorized access are to be checked to verify that they are functioning correctly. Emergency overspeed governors are to be tested.

9.2.11 Where batteries provide the source of power for any essential services, their installation, including charging and ventilation, is to be examined.

Section 10
Screwshafts, tube shafts, propellers and water jet units

10.1 Frequency of surveys

10.1.1 Shafts with keyed propeller attachments and fitted with continuous liners or approved oil glands, or made of approved corrosion resistant materials, are to be surveyed at intervals of five years when the keyway complies fully with the present Rules.

10.1.2 Shafts having keyless type propeller attachments are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

10.1.3 Shafts having solid coupling flanges at the after end are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

10.1.4 All other shafts not covered by 10.1.1 to 10.1.3 are to be surveyed at intervals of $2^1/_2$ years.

10.1.5 Controllable pitch propellers for main propulsion purposes are to be surveyed at the same intervals as the screwshaft.

10.1.6 Directional propeller units for main propulsion purposes are to be surveyed at intervals not exceeding five years.

10.1.7 Water jet units for main propulsion purposes are to be surveyed at intervals not exceeding five years provided the impeller shafts are made of approved corrosion resistant material or have approved equivalent arrangements.

10.1.8 Athwartship thrust propellers and shaftings are to be surveyed at intervals not exceeding five years, *see* 6.2.2.

10.2 Normal surveys

10.2.1 All screwshafts are to be withdrawn for examination by LR's Surveyors at the intervals prescribed in 10.1.1 to 10.1.4. The after end of the cylindrical part of the shaft and forward one third of the shaft cone, or fillet of the flange, is to be examined by a magnetic particle crack detection method. In the case of a keyed propeller attachment at least the forward one third of the shaft cone is to be examined with the key removed. Weardown is to be measured and the sterntube bearings, oil glands, propellers and fastenings are to be examined. Controllable pitch propellers where fitted are to be opened up and the working parts examined, together with the control gear.

10.2.2 Directional propeller units are to be dismantled for examination of the propellers, shafts, gearing and control gear.

10.2.3 Water jet units are to be dismantled for examination of the impeller, casing, shaft, shaft seal, shaft bearing, inlet and outlets channels, steering nozzle, reversing arrangements, and control gear.

10.3 Screwshaft Condition Monitoring (SCM)

10.3.1 Where oil lubricated shafts with approved oil glands are fitted, and the Owner has complied with the following requirements, the descriptive note **SCM** (Screwshaft Condition Monitoring) may be assigned:

(a) Lubricating oil analysis to be carried out regularly at intervals not exceeding six months. The lubricating oil analysis documentation is to be available on board. Each analysis is to include the following minimum parameters:
  - water content
  - chloride content
  - bearing material and metal particles content
  - oil ageing (resistance to oxidation).

(b) Oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube.

(c) Oil consumption is to be recorded.

(d) Bearing temperatures are to be recorded, (two temperature sensors or other approved arrangements are to be provided).

(e) Facilities are to be provided for measurement of bearing weardown.

(f) Oil glands are to be capable of being replaced without withdrawal of the screwshaft.

10.3.2 For maintenance of the descriptive note **SCM**, the records of analyses, consumption and temperatures, together with weardown readings are to be retained on board and audited annually.

10.3.3 Where the requirements for the descriptive note **SCM** have been complied with, the screwshaft need not be withdrawn at surveys as required by 10.2.1 provided all condition monitoring data is found to be within permissible limits and all exposed areas of the shaft are examined by a magnetic particle crack detection method. The remaining requirements of 10.2.1 are to be complied with. Where the Surveyor considers that the data presented is not entirely to his satisfaction the shaft will be required to be withdrawn in accordance with 10.2.1.

10.4 Modified Survey

10.4.1 A Modified Survey may be accepted at alternate five-yearly surveys for shafts described in 10.1.1 provided they are fitted with oil lubricated bearings and approved oil glands, and also for those in 10.1.2 and 10.1.3.

10.4.2 The Modified Survey is to consist of the partial withdrawal of the shaft, sufficient to ascertain the condition of the stern bearing and shaft in way. For keyless propellers or shafts with a solid flange connection to the propeller a visual examination to confirm the good condition of the sealing arrangements is to be made. The oil glands are to be capable of being replaced without removal of the propeller. The forward bearing and all accessible parts including the propeller connection to the shaft are to be examined as far as possible.

Wear-down is to be measured and found satisfactory. Where a controllable pitch propeller is fitted, at least one of the blades is to be dismantled complete for examination of the working parts and the control gear.

10.4.3 For keyed propellers, the after end of the cylindrical part of the shaft and forward one third of the shaft cone is to be examined by a magnetic particle crack detection method, for which dismantling of the propeller and removal of the key will be required.

10.4.4 Where the descriptive note **SCM** has been assigned as described in 10.3.1 and all data is found to be within permissible limits, partial withdrawal of the shaft may not be required. Where doubt exists regarding any of the above findings the shaft is to be withdrawn to permit an entire examination.

10.5 Partial Survey

10.5.1 For shafts where the Modified Survey is applicable, upon application by the Owner, the Committee will be prepared to give consideration to postponement of the survey for a maximum period of half the specified cycle provided a Partial Survey is held.

10.5.2 The Partial Survey is to consist of the propeller being backed off in any keyed shaft and the top half of the cone examined by an efficient crack detection method for which removal of the key will be required. Oil gland and seals are to be examined and dealt with as necessary. Weardown is to be measured and found satisfactory. Propeller and fastenings are to be examined.

10.5.3 The Committee will be prepared to give consideration to the circumstances of any special case upon application by the Owner.

■ *Section 11*
Surveys of unclassed machinery in existing classed yachts

11.1 General

11.1.1 The requirements of this survey are considered necessary in order to establish, so far as practicable, that the unclassed machinery installation does not constitute a hazard to the classed hull. The survey is applicable only to existing sailing yachts fitted with unclassed auxiliary propulsion engines not exceeding 37 kW.

11.1.2 At any time when unclassed machinery in an existing classed yacht is undergoing alteration and/or replacement, the requirements of Ch 2,4.4.5 are to be complied with.

11.2 Intermediate and Docking Surveys

11.2.1 For Intermediate and Docking Surveys, *see* Sections 2 and 3.

11.3 Complete Surveys

11.3.1 At each Special Survey of the hull the requirements of 11.2.1 and the following are to be complied with:

(a) The bilge pumping system is to be examined and tested under working conditions.
(b) A general examination is to be made of the fuel tanks and fuel system with their valves, pipes and fittings, and of the engine exhaust system, piping and fittings.
(c) A general examination of the electrical equipment is to be made and, if considered necessary, a test of the insulation resistance is to be carried out in accordance with 9.2.1.
(d) The starting arrangements are to be examined.
(e) The screwshafts and tube shafts are to be withdrawn for examination.
(f) The main and essential auxiliary machinery is to be examined under full working conditions in accordance with 8.1.4.

■ *Section 12*
Classification of yachts not built under survey

12.1 General

12.1.1 When classification is desired for a yacht not built under the supervision of LR's Surveyors, application should be made to the Committee in writing.

12.1.2 Periodical Surveys of such yachts, when classed, are subsequently to be held as in the case of yachts built under survey.

12.1.3 Where classification is desired for a yacht which is classed by another recognized Society, special consideration will be given to the scope of the survey.

12.2 Hull and equipment

12.2.1 Plans showing the main scantlings and arrangements of the actual yacht together with any proposed alterations are to be submitted for approval.These should comprise plans of the midship section, longitudinal section and decks, and such other plans as may be requested. If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the yacht.

12.2.2 Particulars of the process of manufacture and the testing of the material of construction are to be supplied. The requirements for composite yachts will be specially considered.

12.2.3 The full requirements of Sections 4 and 5 are to be carried out as applicable. Yachts of recent construction will receive special consideration.

12.2.4 During the survey, the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements. For this purpose, and also in order to ascertain the amount of any deterioration of steel yachts, parts of the structure will require to be gauged as necessary. Full particulars of the anchors, chain cables and equipment are to be submitted. For yachts to which Pt 17, Ch 1 applies, fire protection, detection and extinction are to be in accordance with the Rules.

12.2.5 When the full survey requirements indicated in 12.2.3 and 12.2.4 cannot be completed at one time, the Committee may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merits of each particular case, which should be submitted for consideration.

12.3 Machinery

12.3.1 To facilitate the survey, the following plans and particulars (plans of piping are to be diagrammatic), together with the particulars of the materials used in the construction of any boilers, air receivers and important forgings are to be submitted:

- Name of manufacturer of engine and gearbox including the manufacturer's type designation of engine and gearbox, together with the continuous shaft power of the engine at the crankshaft coupling with the revolutions per minute of crankshaft and propeller.
- General pumping arrangements, including air and sounding pipes (Builder's plan).
- Bilge, ballast and oil fuel pumping arrangements including the capacities of the pumps on bilge service.
- Arrangement and dimensions of any steam pipes.
- Arrangement of oil fuel pipes and fittings at settling and service tanks.
- Arrangement of oil fuel piping in connection with oil burning installations.
- Oil fuel overflow systems, where these are fitted.
- Arrangement of boiler feed systems.
- Oil fuel settling, service and other oil fuel tanks not forming part of the craft's structure.
- Boilers and economizers.
- Air receivers.
- Crank, thrust, intermediate and screw shafting.
- Details of water jet or directional propeller units, if fitted.
- Clutch and reversing gear with methods of control.
- Reduction gearing.
- Propeller (including spare propeller if supplied) where the diameter exceeds 1m.
- Electrical circuits.
- Arrangement of compressed air systems for main and auxiliary services.
- Arrangement of lubricating oil, other flammable liquids and cooling water systems for main and auxiliary services.
- Steering gear including control arrangement.
- Arrangement of exhaust system indicating materials, method of cooling, and if water spray injected, the method of draining.

12.3.2 Plans additional to those detailed in 12.3.1 are not to be submitted unless the machinery is of a novel or special character affecting classification.

12.3.3 Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted.

12.3.4 For new yachts and yachts which have been in service less than two years, calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration, as required for yachts constructed under Special Survey. For older yachts the circumstances will be specially considered in relation to their service record and type of machinery installed. Where calculations are not submitted, the Committee may require that the machinery certificate be endorsed to this effect. When desired by the Owner, the calculations and investigation of the torsional vibration characteristics of the machinery may be carried out by LR upon special request.

12.3.5 The main and auxiliary machinery, feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys. Working pressures are to be determined from the actual scantlings in accordance with the Rules.

12.3.6 The screwshaft is to be drawn and examined.

12.3.7 Any steam pipes or oil burning installations are to be examined and tested as required by Pt 1, Ch 3,15 or Ch 3,16 of the Rules for Ships.

12.3.8 The bilge, ballast and oil fuel pumping arrangements are to be examined and amended, as necessary, to comply with the Rules.

12.3.9 The electrical equipment is to be examined as required at Complete Surveys.

12.3.10 The whole of the machinery, including essential controls, is to be tried under working conditions to the Surveyor's satisfaction.

Periodical Survey Regulations for Amphibious Air Cushion Vehicles (ACV)

Section

■ *Section 1* General

1.1 Frequency of surveys

1.1.1 Except as amended at the discretion of the Committee, the periods between surveys are as follows:

(a) Annual Surveys are to be held within three months before or after each anniversary of the completion, commissioning or Special Survey.
(b) Intermediate Surveys are to be held instead of the second or third Annual Survey after completion, commissioning or Special Survey.
(c) Special Surveys (hull and machinery) are to be held at the fifth anniversary after completion, commissioning or previous Special Survey.

1.2 Machinery surveys

1.2.1 The manufacturer's approved operating and service instructions for the main and auxiliary power units, transmission systems, propellers and lift fans are to be incorporated into an approved planned maintenance scheme for the ACV.

1.2.2 Maintenance, overhaul or replacement will then normally be determined by the specified condition/ performance monitoring limits and running hours.

1.2.3 It is a requirement of this arrangement that any significant defect, damage repair or alteration be reported to Lloyd's Register (hereinafter referred to 'LR') without delay, *see also* Ch 2,1.1.7.

1.3 Surveys for damage, repairs or alterations

1.3.1 At any time when an ACV is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g. if any part of the main or auxiliary machinery is removed for any reasons, the hull structure in way is to be carefully examined by the Surveyor.

1.3.2 All significant repairs, alterations, approved modifications and replacements are to be recorded in the ACV's Log Books in a manner that will enable their later identification by the Surveyors, *see also* Ch 2,4.4.1 and 4.4.5.

1.3.3 Trials are to be made on any craft which have been significantly modified, overhauled or repaired, prior to returning to service, to ensure to the Surveyor's satisfaction that the ACV has been returned in a satisfactory condition for its intended service.

1.4 Unscheduled surveys

1.4.1 In the event that LR has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull or machinery.

1.5 Surveys for the issue of Convention Certificates

1.5.1 Surveys are to be held either by LR when so appointed or by the Exclusive Surveyors of a National Administration when so delegated by a Flag State.

■ *Section 2* Annual Surveys – Hull and machinery requirements

2.1 General

2.1.1 Annual Surveys are to be held concurrently with any relevant statutory annual or other statutory surveys, wherever practicable.

2.1.2 The Surveyor is to audit the approved planned maintenance scheme. The records will be checked and the satisfactory operation of the scheme verified. Condition monitoring data will be reviewed and trends analysed.

2.1.3 The Surveyor is to examine the Log Book to verify that a proper record has been kept in respect of servicing, maintenance and overhaul requirements for those aspects not covered by the approved planned maintenance scheme.

2.1.4 Certification for replacement units/parts will be required.

2.2 Preparation

2.2.1 The ACV is to be slung or jacked up to permit a thorough inspection of all underside parts, fittings and attachments.

2.2.2 Panelling, floor coverings, etc. need not be removed at these surveys, unless they are of portable type or unless the Surveyor has reason to suspect they may conceal significant damage.

2.3 Hull items

2.3.1 The Surveyor is to be satisfied as to the efficient condition of the following items:

(a) Bottom and side plating, any external stiffeners, and side walls or skirts, including flexible keels, if any.
(b) Weather doors, ventilators, windows and emergency or other hatches.
(c) Weather decks, houses, etc.
(d) Machinery casings and seats.
(e) Anchoring and mooring equipment when required by the Rules.
(f) Fire equipment including fire detection, alarm systems and means of escape , where the survey of such items is not covered by statutory certification.
(g) Where applicable, passenger seat foundations and cargo tie down points.
(h) Skirt attachment and operating mechanisms.
(j) Air propeller shroud structures.
(k) Side body attachments and supports (when fitted).
(l) Operation of ramps, and their closing and locking arrangements.
(m) The structural attachment and retention arrangements for external fuel tanks (when fitted).

2.4 Machinery items

2.4.1 The Surveyor is to be satisfied as to the efficient condition of the following items:

(a) Fuel tanks and associated fuel system with pumps, filters, etc.
(b) Lubricating oil tanks and associated lubricating system with coolers, pumps, filters, etc.
(c) The bilge pumping system.
(d) Machinery alarm arrangements.
(e) The electrical machinery, the switchgear and other electrical equipment are to be generally examined under operating conditions so far as practicable. The satisfactory operation of the emergency source of power, including the automatic controls as fitted, is to be verified.
(f) Hydraulic, electrical and pneumatic control systems, including steering, are to be examined under operating conditions.
(g) Engine starting arrangements.
(h) All drive belts, associated running surfaces and tension adjustment (where fitted).
(j) Air propellers, including (where fitted) hub assemblies, servos and actuating equipment of controllable pitch propellers.
(k) The overall operation of the machinery including propulsion and lift machinery. A machinery proving trial of short duration is to demonstrate to the Surveyor the satisfactory operation of the machinery.

■ *Section 3*
Intermediate Surveys – Hull and machinery requirements

3.1 General

3.1.1 The requirements of Section 2 are to be complied with.

3.2 Preparation

3.2.1 A sufficient amount of panelling, floor covering, insulation and paint etc., is to be removed to enable the Surveyors to satisfy themselves that all major structural items are in a satisfactory condition.

3.3 Examination and testing

3.3.1 Representative integral tanks and buoyancy spaces are to be examined as necessary to ensure that they continue to be in a satisfactory condition.

3.3.2 At the discretion of the Surveyor, tanks or buoyancy spaces may require to be tested to ensure that they continue to be tight.

■ *Section 4*
Special Surveys (Hull and machinery)

4.1 General

4.1.1 The requirements of Sections 2 and 3 are to be complied with.

4.2 Hull Surveys

4.2.1 All integral tanks and buoyancy spaces are to be examined and tested to ensure that they continue to be tight and in a satisfactory condition.

4.2.2 All other hull compartments are to be examined.

4.2.3 The anchoring and mooring equipment, when required by the Rules, is to be examined to ensure its efficiency, accessibility and readiness for use. Anchor cables or warps are to be ranged for examination.

4.3 Machinery Surveys

4.3.1 The main and essential auxiliary machinery is to be generally examined with particular attention given to safety devices, fastening arrangements and resilient mountings. A limited opening up, e.g. removal of inspection covers, should be undertaken in order that the Surveyor can confirm the satisfactory condition of these items.

4.3.2 Where not carried out as a regular monitoring procedure, lubricating oil analysis may be required.

4.3.3 Items that have not been overhauled as part of the approved planned maintenance scheme since installation, commissioning or the previous Special Survey may require to be opened up for examination.

4.3.4 The insulation resistance of the electrical equipment and connections is to be tested.

■ *Section 5*
Classification of ACVs not built under survey

5.1 General

5.1.1 The requirements for classification of an ACV not built under the supervision of LR's Surveyors are to be in accordance with the applicable sub-Sections of Pt 1, Ch 3,12.

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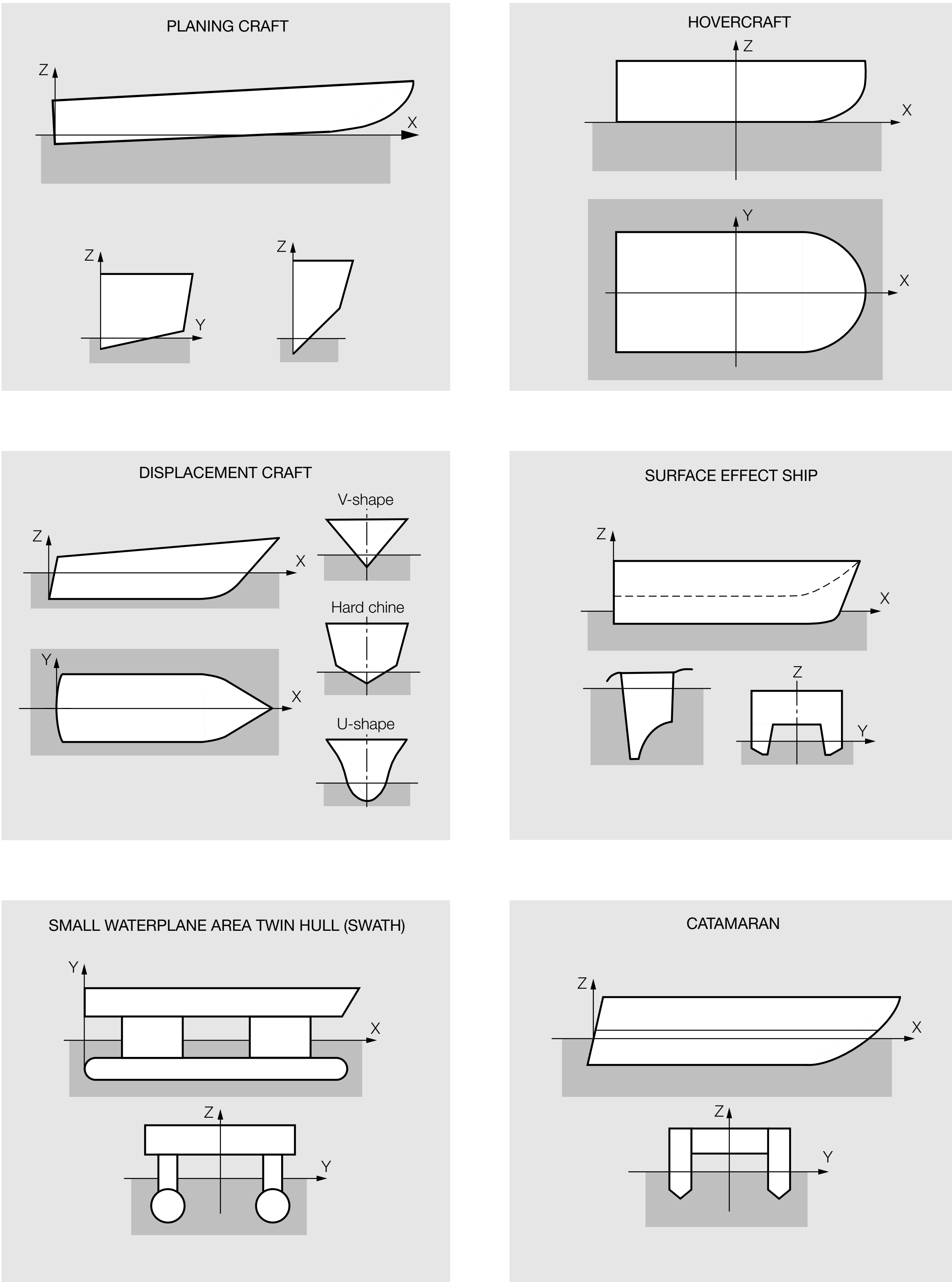
DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES



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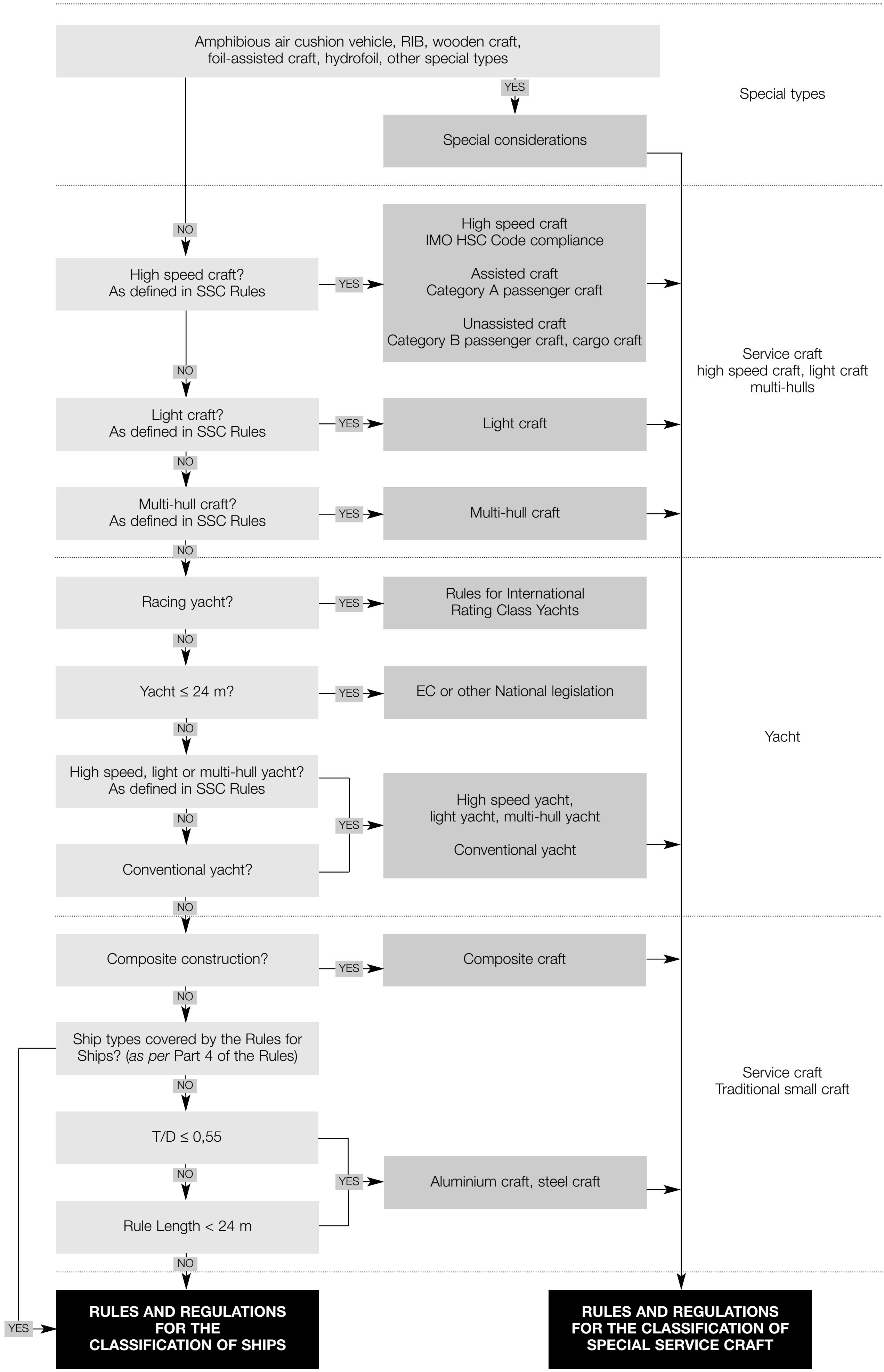

RULES AND REGULATIONS FOR THE CLASSIFICATION OF SPECIAL SERVICE CRAFT

GENERAL REQUIREMENTS AND CONSTRUCTIONAL ARRANGEMENTS

JULY 2008

VOLUME 3

PART 3

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Section 1
Rules application

1.1 General

1.1.1 The Rules apply to sea-going motor, sailing and auxiliary craft of normal form, proportions and speed, generally not exceeding a Rule length, L_R of 150 m.

1.2 Exceptions

1.2.1 Craft of unusual form, proportions or speed, or intended for the carriage of special cargoes, or for special or restricted service, not covered specifically by the Rules, will receive individual consideration based on the general standards of the Rules.

1.3 Loading

1.3.1 The Rules are framed on the understanding that craft will be properly loaded and handled; they do not, unless it is stated or implied in the class notation, provide for special distributions or concentrations of loading other than those included in the approved Loading Manual. The Committee may require additional strengthening to be fitted in any craft which, in their opinion, would otherwise be subjected to severe stresses due to particular features of the design, or where it is desired to make provision for exceptional load or ballast conditions.

1.4 Advisory services

1.4.1 The Rules do not cover certain technical characteristics, such as stability except as mentioned in Pt 1, Ch 2,1.1.11, 1.1.13 and 1.1.14, trim, vibration, docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

Section 2
Direct calculations

2.1 General

2.1.1 Direct calculations may be specifically required by the Rules or may be required for craft having novel design features, as defined in 1.2, or may be submitted in support of alternative arrangements and scantlings. Lloyd's Register (hereinafter referred to as 'LR') may, when requested, undertake calculations on behalf of designers and make recommendations in regard to suitability of any required model tests.

2.1.2 Where model testing is undertaken to complement direct calculations the following details would normally be required to be submitted: Schedule of tests, details of test equipment, input data, analysis and calibration procedure together with tabulated and plotted output.

2.2 Submission of direct calculations

2.2.1 In cases where direct calculations have been carried out, the following supporting information should be submitted as applicable:

(a) Reference to the direct calculation procedure and technical program used.
(b) A description of the structural modelling.
(c) A summary of analysis parameters including properties and boundary conditions.
(d) Details of the loading conditions and the means of applying loads.
(e) A comprehensive summary of calculation results. Sample calculations should be submitted where appropriate.

2.2.2 In general, submission of large volumes of input and output data associated with such programs as finite element analysis will not be necessary.

2.2.3 The responsibility for error free specification and input of program data and the subsequent correct transposal of output rests with the Builder.

2.3 Global hull strength

2.3.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding that specified in Chapter 6, of Parts 6, 7 and 8, for steel, aluminium alloy and composite respectively, covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water bending moments and shear forces are to be calculated for both departure and arrival conditions and for any special mid-voyage conditions caused by changes in ballast distribution.

2.3.2 Where the Rule length, L_R, does not exceed that indicated in 2.3.1, longitudinal strength calculations may be required at LR's discretion, dependent upon craft proportions, the proposed loading, structural configuration and material of construction.

Section 3 Equivalents

3.1 Alternative arrangements and scantlings

3.1.1 In addition to cases where direct calculations are specifically required by the Rules, LR will consider alternative arrangements and scantlings which have been derived by direct calculations in lieu of specific Rule requirements. All direct calculations are to be submitted for examination.

3.1.2 Where calculation procedures other than those available within the LR *Software Guide* are employed, supporting documentation is to be submitted for appraisal and this is to include details of the following:
- calculation methods;
- assumptions and references;
- loading;
- structural modelling;
- design criteria and their derivation, e.g. permissible stresses;
- factors of safety against plate panel instability, etc.

3.1.3 LR will be ready to consider the use of Builder's programs for direct calculations in the following cases:
(a) Where it can be established that the program has previously been satisfactorily used to perform a direct calculation similar to that now submitted.
(b) Where sufficient information and evidence of satisfactory performance is submitted to substantiate the validity of the computation performed by the program.

3.1.4 Alternative arrangements or fittings which are considered to be equivalent to the Rule requirements will be accepted.

3.1.5 Where no special reference is made in this Part to specific requirements, the construction is to be efficient for the intended purpose and to conform to good practice.

3.1.6 Where items are of a novel or unconventional design or manufacture, it is the responsibility of the Builder to demonstrate their suitability and equivalence to the Rule requirements.

3.1.7 Alternative arrangements which are in accordance with the requirements of a National Authority may be accepted as equivalent to the requirements of this Part of the Rules.

Section 4 National and International Regulations

4.1 International Conventions

4.1.1 The Committee, when authorised, will act on behalf of Governments and, if requested, LR will certify compliance in respect of National and International statutory safety and other requirements for passenger and cargo craft.

4.1.2 In satisfying the Load Line Convention, the general structural strength of the craft is required to be sufficient for the draught corresponding to the freeboards to be assigned. Craft built and maintained in accordance with LR's Rules and Regulations possess adequate strength to satisfy the Load Line Convention. However, some National Authorities may, in addition, require to be supplied with calculations of bending moments and shear forces for certain conditions of loading.

4.2 International Association of Classification Societies (IACS)

4.2.1 Where applicable, the Rules take into account unified requirements and interpretations established by IACS.

4.3 International Maritime Organisation (IMO)

4.3.1 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside the scope of classification as defined in these Rules and Regulations.

Section 5 Information required

5.1 General

5.1.1 The categories and lists of information required are given in 5.2.

5.1.2 Plans are generally to be submitted in triplicate, but one copy only is necessary for supporting documents and calculations.

5.1.3 Plans are to contain all necessary information to fully define the structure, including construction details, equipment and systems as appropriate.

5.1.4 Additional requirements for individual craft types are given in subsequent Chapters.

5.2 Submission of plans and data

5.2.1 Plans and data required to be submitted are indicated in Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively, as appropriate.

5.2.2 Where an ***IWS** (In-water Survey) notation is to be assigned, *see* Pt 1, Ch 2,3.8.2, plans and information covering the following items are to be submitted:
- Details showing how rudder pintle and bush clearances are to be measured and how the security of the pintles in their sockets are to be verified with the craft afloat.
- Details showing how stern bush clearances are to be measured with the craft afloat.
- Details of high resistant paint, for information only.

5.3 Standard designs

5.3.1 Where a craft is a standard design produced in several versions, the plans and data are to clearly define the differences between each version.

5.3.2 Where the craft is a Builder's standard design to be built from previously approved plans and data, a schedule of applicable plans, etc., is to accompany the Request for Survey. Plans of any proposed modifications and changes to the previously approved plans are to be submitted for approval prior to the commencement of any work.

5.3.3 Plan approval of standard designs is only valid so long as no applicable Rule changes take place. When the Rules are amended, the plans for standard types are to be submitted for re-approval.

5.4 Plans and data to be supplied to the craft

5.4.1 To facilitate the ordering of materials for repairs, plans are to be carried in the craft indicating the disposition and grades (other than Grade A) of hull structural steel, the extent and location of higher tensile steel together with details of specification and mechanical properties, and any recommendations for welding, working and treatment of these steels.

5.4.2 Similar information is to be provided when aluminium alloy, fibre composite or other materials are used in the hull construction.

5.4.3 A copy of the final Loading Manual, (where applicable) when approved, and details of the loadings applicable to approved decks, hatch covers and inner bottom are to be placed on board the craft.

5.4.4 Details of any corrosion control system fitted are to be placed on board the craft.

5.4.5 Copies of main scantling plans are to be placed on board.

5.4.6 Where an ***IWS** (In-water Survey) notation is to be assigned, approved plans and information covering the items detailed in 5.2.2 are to be placed on board.

5.5 Fire protection, detection and extinction

5.5.1 For information and plans required, *see* Part 17.

■ *Section 6* Definitions

6.1 General

6.1.1 The following definitions apply except where they are inappropriate or where specifically defined otherwise.

6.2 Principal particulars

6.2.1 **Rule length**, L_R, is the distance, in metres, on the summer load waterline from the forward side of the stem to the after side of the rudder post or to the centre of the rudder stock if there is no rudder post. L_R is to be not less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on the summer load waterline. In craft without rudders, the Rule length, L_R, is to be taken as 97 per cent of the extreme length on the summer load waterline. In craft with unusual stem or stern arrangements the Rule length, L_R, will be specially considered.

6.2.2 **Length between perpendiculars**, L_{pp}, is the distance, in metres, on the summer load waterline from the fore side of the stem to the after side of the rudder post, or to the centre of the rudder stock if there is no rudder post. In craft with unusual stern arrangements the length, L_{pp}, will be specially considered. The forward perpendicular, F.P., is the perpendicular at the intersection of the summer load waterline with the fore side of the stem. The after perpendicular, A.P., is the perpendicular at the intersection of the summer load waterline with the after side of the rudder post or to the centre of the rudder stock for craft without a rudder post.

6.2.3 **Load line length**, L_L, is to be taken as 96 per cent of the total length on a waterline at 85 per cent of the least moulded depth measured from the top of the keel, or as the length from the fore side of the stem to the axis of the rudder stock on that waterline, if that is greater. In craft designed with a rake of keel, the waterline on which this length is measured is to be parallel to the designed waterline. The length L_L is to be measured in metres.

6.2.4 **Length overall**, L_{OA}, is the distance, in metres, measured parallel to the static load waterline from the foreside of the stem to the after side of the stern or transom, excluding rubbing strakes and other projections.

6.2.5 **Length waterline**, L_{WL}, is the distance, in metres, measured on the static load waterline from the foreside of the stem to the after side of the stern or transom.

6.2.6 **Amidships** is to be taken as the middle of the Rule length, L_R, measuring from the forward side of the stem.

6.2.7 **Breadth**, B, is the greatest moulded breadth, in metres, or, for craft of composite construction, the extreme breadth excluding rubbing strakes or other projections. For multi-hull craft it is to be taken as the sum of the breadths of the individual hulls.

6.2.8 **Depth**, D, is measured, in metres, at the middle of the Rule length, L_R, from top of keel to top of the deck beam at side on the uppermost continuous deck, or as defined in appropriate Chapters. When a rounded gunwale is arranged, the depth D is to be measured to the continuation of the moulded deck line at side.

6.2.9 **Draught**, T, is the summer draught, in metres, measured from top of keel.

6.2.10 **Block coefficient**, C_b, is the moulded block coefficient at draught T corresponding to summer load waterline, based on Rule length L_R and moulded breadth B, as follows:

$$C_b = \frac{\text{moulded displacement (m}^3\text{) at draught } T}{L_R\, B\, T}$$

6.3 Freeboard deck

6.3.1 The freeboard deck is normally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all openings in the weather part thereof, and below which all openings in the sides of the craft are fitted with permanent means of watertight closing. It is the deck from which the freeboard is measured.

6.4 Bulkhead deck

6.4.1 Bulkhead deck is the uppermost deck up to which the transverse watertight bulkheads are carried.

6.5 Strength deck

6.5.1 Strength deck is normally the uppermost continuous deck. Other decks may be considered as the strength deck provided that such decks are structurally effective.

6.6 Weather deck

6.6.1 A weather deck is a deck which is exposed to sea and weather loads.

6.6.2 The weather deck is the lowest continuous deck exposed to sea and weather loads, and is not to be taken lower than the bulkhead deck for the determination of the requirements for closing appliances from Chapter 4.

6.7 Wet deck

6.7.1 A wet deck is the lower most exposed surface of the cross-deck structure, connecting the hulls of a multi-hull craft.

6.8 Weathertight

6.8.1 A closing appliance is considered weathertight if it is designed to prevent the passage of water into the craft in any sea conditions.

6.8.2 Generally, all openings in the freeboard deck and in enclosed superstructures are to be provided with weathertight closing appliances.

6.9 Watertight

6.9.1 A closing appliance is considered watertight if it is designed to prevent the passage of water in either direction under a head of water for which the surrounding structure is designed.

6.9.2 Generally, all openings below the freeboard deck in the outer shell/envelope (and in main bulkheads) are to be fitted with permanent means of watertight closing.

6.10 Position 1 and Position 2

6.10.1 For the purpose of Load Line Conditions of Assignment, there are two basic positions of hatchways, doorways and ventilators defined as follows:

Position 1 — Upon exposed freeboard and raised quarterdecks, and exposed superstructure decks within the forward 0,25 of the Load Line length, L_L.

Position 2 — Upon exposed superstructure decks abaft the forward 0,25 of the load line length, L_L and located at least one standard height of superstructure above the freeboard deck.

Upon exposed superstructure decks within the forward 0,25 of the Load Line length, L_L and located at least two standard heights of superstructure above the freeboard deck.

6.11 Reference system

6.11.1 For hull reference purposes, the craft is divided into 21 equally spaced stations where Station 0 is the after perpendicular, Station 20 is the forward perpendicular, and Station 10 is mid-L_{pp}.

6.12 Co-ordinate system

6.12.1 Unless otherwise stated, the co-ordinate system is as shown in Fig. 1.6.1, that is, a right-hand co-ordinate system with the X axis positive forward, the Y axis positive to port and the Z axis positive upwards. Angular motions are considered positive in a clockwise direction about the X, Y or Z axes.

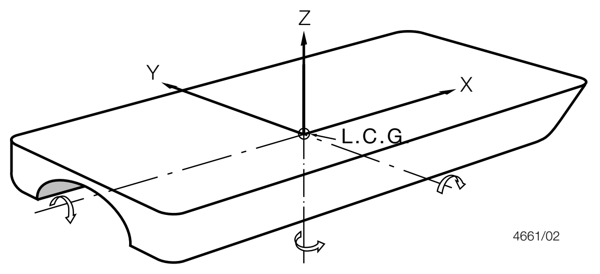


Fig. 1.6.1 Co-ordinate system

6.13 Superstructure

6.13.1 A superstructure is defined as a decked structure on the freeboard deck, extending from side to side of the craft, or with the side plating being less than four per cent of the breadth, *B*, inboard of the shell plating.

6.13.2 An enclosed superstructure is a superstructure with:
(a) Enclosing bulkheads of efficient construction;
(b) Access openings, if any, in these bulkheads fitted with doors complying with the requirements of Ch 4,6.5;
(c) All other openings in sides or ends of the superstructure fitted with efficient weathertight means of closing.

6.13.3 The standard height of superstructure for L_L of 75 m or less is to be taken as 1,8 m, and for L_L of 125 m or greater is to be taken as 2,3 m. Intermediate values are to be determined by linear interpolation.

6.14 Deckhouse

6.14.1 A deckhouse is in general defined as a decked structure on or above the freeboard deck with side plating being four per cent or more of the breadth, *B*, inboard of the shell plating.

■ *Section 7*
Inspection, workmanship and testing procedures

7.1 General

7.1.1 The minimum requirements in respect of inspection, workmanship and testing are contained within Chapter 2, of Parts 6, 7 and 8, of the Rules for craft constructed in steel, aluminium alloy and composite respectively.

7.2 Construction standards

7.2.1 Construction standards for all materials are to be in accordance with National Standards or these Rules whichever are the higher.

7.2.2 The design requirements for welding and structural detail are to be found in Parts 6 and 7 of the Rules for craft constructed in steel and aluminium alloy respectively.

7.2.3 The design requirements for the bonding of all structural detail of composite materials are contained in Part 8.

7.3 Testing procedures

7.3.1 **Definitions.** For the purpose of these procedures the following definitions apply:
(a) **Protective coating** is the coating system applied to protect the structure from corrosion. This excludes the prefabrication primer.
(b) **Structural testing** is a hydrostatic test carried out to demonstrate the tightness of the tanks and the structural adequacy of the design. Where practical limitations prevail and hydrostatic testing is not feasible, hydro-pneumatic testing, *see* (e), may be carried out instead.
(c) **Leak testing** is an air or other medium test carried out to demonstrate the tightness of the structure.
(d) **Hose testing** is carried out to demonstrate the tightness of structural items not subjected to hydrostatic or leak testing, and other components which contribute to the watertight or weathertight integrity of the hull.
(e) **Hydropneumatic testing** is a combination of hydrostatic and air testing, consisting of filling the tank with water and applying an additional air pressure. The conditions are to simulate, as far as practicable, the actual loading of the tank and in no case is the air pressure to be less than given in 7.3.4.

7.3.2 **Application**. The testing requirements for tanks, including independent tanks, watertight and weathertight compartments, are listed in Table 1.7.1. Tests are to be carried out in the presence of the Surveyor at a stage sufficiently close to completion such that the strength and tightness are not subsequently impaired.

7.3.3 **Structural testing**. The attachment of fittings to oiltight surfaces is to be completed before tanks are structurally tested. Where it is intended to carry out structural tests after the protective coating has been applied welds are generally to be leak tested prior to the coating application.

For welds other than manual and automatic erection welds, manual fillet welds on tank boundaries and manual penetration welds, the leak test may be waived provided that careful visual inspection is carried out, to the satisfaction of the Surveyor, before the coating is applied. The cause of any discolouration or disturbance of the coating is to be ascertained, and any deficiencies repaired.

7.3.4 **Leak testing**. This is carried out by applying an efficient indicating liquid (e.g. soapy water solution) to the weld or outfitting penetration being tested, while the tank or compartment is subject to an air pressure of at least 0,15 bar (0,15 kgf/cm^2).

It is recommended that the air pressure be raised to 0,2 bar (0,2 kgf/cm^2) and kept at this level for about one hour to reach a stabilized state, with a minimum number of personnel in the vicinity, and then lowered to the test pressure prior to inspection. A U-tube filled with water to a height corresponding to the test pressure is to be fitted for verification and to avoid overpressure. The U-tube is to have a cross-section larger than that of the air supply pipe. In addition, the test pressure is to be verified by means of a pressure gauge, or alternative equivalent system.

Table 1.7.1 Testing requirements

Item to be tested	Testing procedure	Testing requirement
Double bottom tanks	Structural (1)	The greater of: – head of water up to the top of the overflow – head of water up to the margin line – head of water representing the maximum pressure experienced in service
Cofferdams	Structural (1)	The greater of: – head of water up to the top of the overflow – 1,8 m head of water above highest point of tank (4)
Forepeak and aft peak used as tank(3)	Structural	
Tank bulkheads	Structural (1)	The greater of: – head of water up to the top of the overflow – 1,8 m head of water above the highest point of tank (4) – setting pressure of the safety valves, where relevant
Deep tanks	Structural (1)	
Scupper and discharge pipes in way of tanks	Structural (1)	
Double plate rudders	Structural (1), (5)	2,4 m head of water, and rudder should normally be tested while laid on its side
Watertight bulkheads, shaft tunnels, flats and recesses, etc.	Hose (2)	*See* 7.3.5
Watertight doors (below freeboard or bulkhead deck) when fitted in place	Hose (6)	
Weathertight hatch covers and closing appliances	Hose	
Forepeak not used as tank	Hose (2)	
Shell doors when fitted in place	Hose (7)	
Chain locker, if aft of collision bulkhead	Structural	Head of water up to the top
Separate oil fuel tanks	Structural	Head of water representing the maximum pressure which could be experienced in service, but not less than 3,5 m
After peak not used as tank	Leak	*See* 7.3.4

NOTES
1. Leak or hydropneumatic testing may be accepted, provided that at least one tank of each type is structurally tested, to be selected in connection with the approval of the design. (*See also* 7.3.9 and 7.3.10).
2. When hose testing cannot be performed without damaging possible outfittings already installed, it may be replaced by a careful visual inspection of all the crossings and welded joints. Where necessary, dye penetrant test or ultrasonic leak test may be required.
3. Testing of the aft peak is to be carried out after the sterntube has been fitted.
4. The highest point of the tank is generally to exclude hatchways. In holds for liquid cargo or ballast with large hatch openings, the highest point of the tank is to be taken to the top of the hatch.
5. If leak or hydropneumatic testing is carried out, arrangements are to be made to ensure that no pressure in excess of 0,30 bar (0,30 kgf/cm^2) can be applied.
6. *See also* SOLAS Reg. II-1/18. Where the door has been subject to the full hydrostatic test before installation, the hose test may be replaced by careful visual examination.
7. For shell doors providing watertight closure, watertightness is to be demonstrated through prototype testing before installation. The testing procedure is to be agreed with LR.

For tanks constructed of steel or aluminium, leak testing is to be carried out, prior to the application of a protective coating, on all fillet welds and erection welds on tank boundaries, excepting welds made by automatic processes and on all outfitting penetrations.

Selected locations of automatic erection welds and pre-erection manual or automatic welds may also be required to be tested before coating, at the discretion of the Surveyor, taking account of the quality control procedures of the shipyard. Where exempt from this requirement, leak testing may be carried out after the protective coating has been applied, provided that the welds have been carefully inspected to the satisfaction of the Surveyor.

7.3.5 **Hose testing**. This is to be carried out at a maximum distance of 1,5 m with a hose pressure not less than 2,0 bar (2,0 kgf /cm^2). The nozzle diameter is not to be less than 12 mm. The jet is to be targeted directly onto the weld or seal being tested.

7.3.6 **Hydropneumatic testing**. When this is performed, the safety precautions identified in 7.3.4 are to be followed.

7.3.7 For tanks of composite construction, leak testing is to be carried out to air pressures as indicated in 7.3.4.

7.3.8 Structural testing may be carried out afloat where testing using water is undesirable in dry-dock or on the building berth. The testing afloat is to be carried out by separately filling each tank and cofferdam to the test head given in Table 1.7.1. Alternate tanks and cofferdams may be filled to the test head and the bottom and lower side shell in the intermediate empty tanks and cofferdams and all boundaries are to be examined and the remainder of the bottom and lower side shell and boundaries examined when the water is transferred to the remaining tanks.

7.3.9 Where permitted by Table 1.7.1, complete structural testing may be replaced by a combination of leak and structural testing, as follows. The leak test is generally to be carried out on each tank while the craft is in dry-dock or on the building berth.

(a) Double bottom tanks and cofferdams may be leak tested on the berth, and structural tests carried out afloat.
(b) All deep tanks are to be structurally tested. However, where a number of similar tanks is involved, one typical tank is to be structurally tested and for the remaining tanks the Surveyor may, at his discretion, permit leak testing in lieu of structural testing.
(c) Interconnecting deep and double bottom tanks and 'flume' type stabilization tanks are to be structurally tested to the test head given in Table 1.7.1.

7.3.10 Equivalent proposals for testing will be considered.

7.3.11 **Trial trip and operational tests**. The items listed in Table 1.7.2 are to be tested on completion of the installation or at sea trials.

Table 1.7.2 Trial trip and operational tests

Item	Requirement
Sliding watertight doors	To be operated under working conditions.
Windlass	An anchoring test is to be carried out in the presence of the Surveyor. The test is to demonstrate that the windlass with brakes, etc., functions satisfactorily and that the power to raise the anchor can be developed and satisfies the Rule requirements. For Rule requirements, *see* Ch 5,8.
Steering gear, main and auxiliary	To be tested under working conditions, to the satisfaction of the Surveyors, to demonstrate that the Rule requirements are met. For Rule requirements, *see* Pt 14, Ch 1.
Davits and deck cranes	To be tested under working conditions to proof load to the satisfaction of the Surveyors.
Fire flaps	To be operated under working conditions to the satisfaction of the Surveyors.
Means of escape	Alternative means of escape from machinery and accommodation spaces is to be proven to the satisfaction of the Surveyors. For Rule requirements, *see* Ch 2,4.10.

■ *Section 8* Building tolerances and associated repairs

8.1 Tolerances – General

8.1.1 Tolerances to be used regarding the acceptability of defects affecting raw materials are to be in accordance with 8.2.

8.1.2 Tolerances to be used for constructional misalignment for all materials are to be discussed between Owners/ Builders and the Surveyor and acceptable Standards agreed subject to the requirements of this Chapter or National Authority requirements where applicable. The permitted degree of inaccuracy/misalignment will vary according to whether the defect is:

(a) In primary structure.
(b) In secondary structure.
(c) Aesthetically pleasing.

8.1.3 The requirements in respect of constructional misalignment of steel/aluminium craft are to be found in 8.6. The requirements for construction using composite materials are contained in Pt 8, Ch 2.

8.2 Raw material surface tolerances

8.2.1 The surface cleanliness of steel/aluminium alloy materials in preparation for painting is to be in accordance with National or paint Manufacturer's Standards.

8.2.2 Where approved corrosion control coatings are to be used the quality of the surface treatment is to be in accordance with the grade specified in the approval documents.

8.3 Surface defects

8.3.1 The limits of depth and extent of surface defects on plate, cast or forged materials in relation to the material plate thickness are shown in Table 1.8.1.

8.3.2 Defects are to be made good by grinding only subject to the plate thickness not being reduced by more than seven per cent of the nominal thickness or 3 mm whichever is the lower, and the area involved not exceeding two per cent of the surface area.

8.3.3 When the limits in 8.3.1 are exceeded, plates are to be made good by grinding or chipping followed by welding.

8.3.4 Where the depth of the deepest imperfection exceeds 20 per cent of the nominal thickness, or the defective area exceeds two per cent of the total surface area, such areas are to be cropped and replaced. *See* 8.5.

8.3.5 Complete removal of the defects is to be verified by suitable non-destructive examination techniques and after welding the repair is to be proved free from further defects.

Table 1.8.1 Limits of surface defects

Normal thickness of material (mm)	Maximum permissible depth of defect (mm)	
	Area affected – Unlimited	Area affected ≤ 5% of Surface
< 8	0,2	0,4
8 to 25	0,3	0,5
25 to 40	0,4	0,6
≥ 40	0,5	0,8

NOTES
1. Defects are to be measured after shot blasting or plate cleaning.
2. The depth of the deepest imperfection is to be considered.
3. Defects not exceeding the limits shown need not be repaired.
4. Where the depth of the defect reduces the material thickness to below the rolling/forging/casting tolerance (stated in Part 2) the values in column 2 and 3 will be accepted provided the areas involved do not exceed 15% and 2% respectively, of the plate/forging/casting surface.
5. Defects exceeding the above limits are to be repaired.
6. Crack-like defects are always to be repaired irrespective of their depth.

8.3.6 Care is to be taken in the repair of defects in higher tensile steel, and aluminium alloy materials. Low hydrogen electrodes with similar properties to the higher tensile steel is to be used with preheating as necessary. Aluminium alloys are to be heat treated after repair, *see* Pt 7, Ch 2,3.

8.4 Plate laminations

8.4.1 Plates in which laminations are suspected or detected are to be ultrasonically tested to determine the full extent of such laminations.

8.4.2 Where laminations are confined to the plate edge, are less than 300 mm long and whose penetration is not more than half the plate thickness, then the defect may be chipped or ground out and rebuilt with weld material.

8.4.3 Where laminations are isolated, located near to the plate surface, and where the total area of the defect does not exceed two per cent of the surface area of the plate, the defect may be repaired as in 8.4.2.

8.4.4 Defective plate, with defects in excess of those stated in 8.4.2 and 8.4.3, is to be cropped back and replaced. *See* 8.5.

8.4.5 Complete removal of the defect is to be verified by non-destructive examination, and after welding, the repair is to be proved free from further defects.

8.5 Part replacement of plates

8.5.1 When defects exceed the limits laid down in 8.3.4 and 8.4.4 above, the portion of the plate affected is to be cropped and replaced, *see* Table 1.8.2.

8.6 Structural misalignment and fit (steel and aluminium)

8.6.1 For the requirements for the alignment and structural continuity of joints, *see* Chapter 2 of Parts 6 and 7.

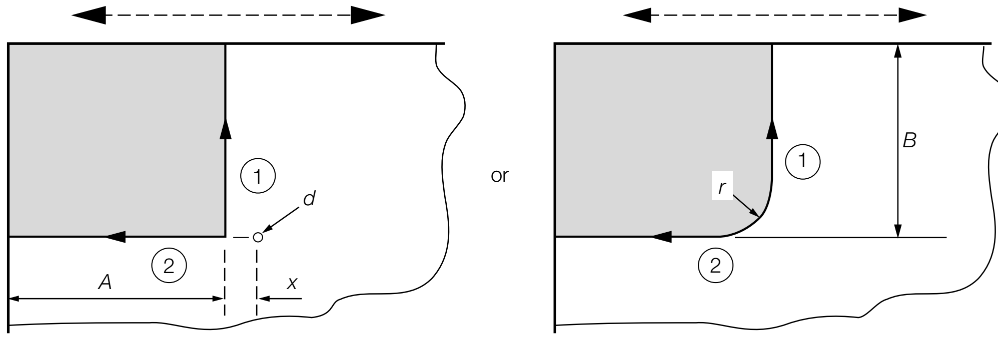
8.6.2 Tables 1.8.3, 1.8.4 and 1.8.5 define the minimum limits of accuracy required to be achieved in the various welded joint designs. When these values are not achieved, the defects are to be discussed and agreed by the Builder and the Surveyor before remedial action is taken.

8.6.3 Welding defects are generally to be dealt with in accordance with Chapter 2 of Parts 6 and 7 depending on materials used. Limits for weld undercut and remedial action to be taken depends on plate thickness and are to be discussed and agreed by the Builder and the Surveyor prior to commencement of repairs.

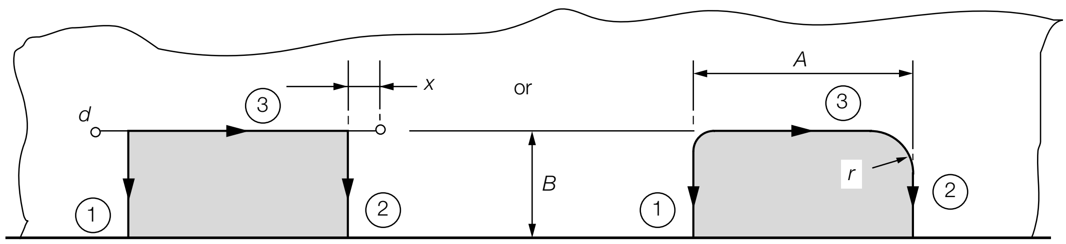
Table 1.8.2 Part replacement of plates

	Parts to be replaced	Shell, strength deck, tank top, top and bottom strakes of longitudinal bulkheads	Elsewhere
A x B	End and corner of plate	1000 x 1000	1000 x 300
	Side of plate	1000 x 300	1000 x 300
	Insert	1000 x 300	1000 x 300

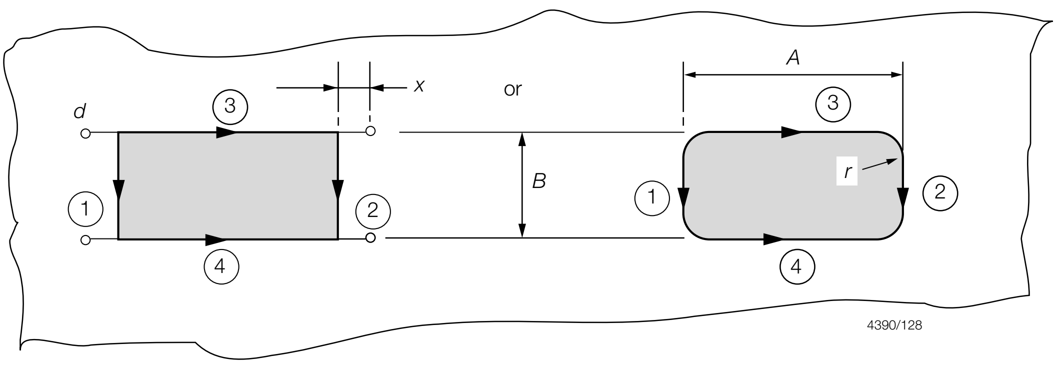
Line of plate replacement to be not less than 100 from extreme edge of defect.
All dimensions are in mm.



(a) Corner or end replacement



(b) Side replacement



(c) Internal replacement

1 Weld sequence

Weld direction

Direction of principal stress

NOTES
1. All dimensions are minimum.
2. Rolling direction of replaced plate to be the same as that of the parent plate.
3. Minimum distance from outermost defect to line of weld – 100 mm.
4. Dimensions in millimetres:
   x = 50
   d = 1,5 x plate thickness with minimum 6 and maximum 20
   r = 75 minimum

Table 1.8.3 Structural misalignment and fit (steel and aluminium)

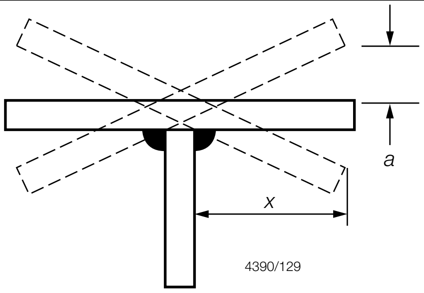
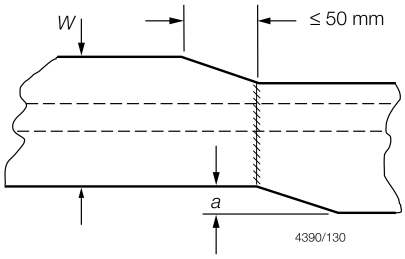
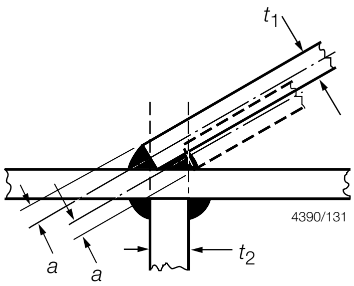
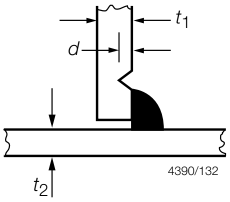
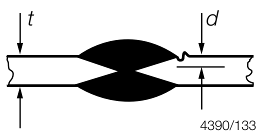
Joint	Location	Acceptable dimensions (mm)	Remedial action	
	Fabricated frames Beams, girders and longitudinals	$a \leq \pm$ 0,03 x	$a > \pm$ 0,03 x	Reject
	Butt welded face flats primary structure Secondary structure	$a \leq 0{,}03W$ (max 6 mm) $a \leq 0{,}04W$ (max 8 mm)	$a > 0{,}03W$ $a > 0{,}04W$	Reject Reject
	Obtuse angle fillet weld	$a \leq t_1/2$	$a > t_1/2$	Reject
	All areas	$d \leq 0{,}1t_1$ (max 0,8 mm)	$d > 0{,}1t_1$	Repair by welding or grinding depends on thickness 't_1' in accordance with 8.3
	All areas	$d \leq 0{,}1t$ (max 0,8 mm)	$d > 0{,}1t$	As above

Table 1.8.4 Structural misalignment and fit (steel and aluminium)

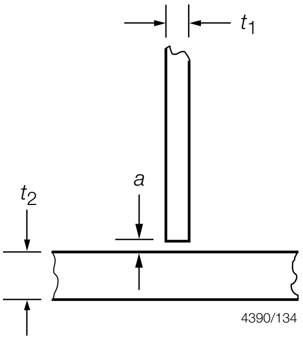
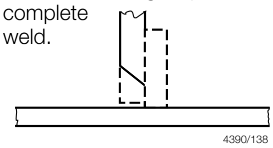
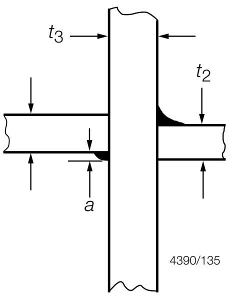
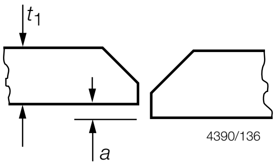
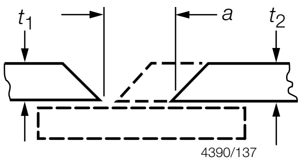
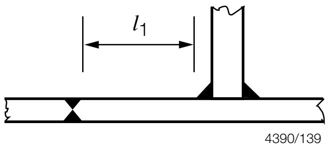
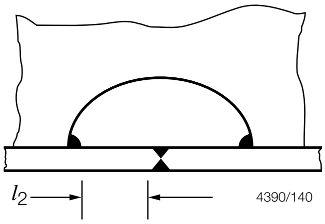
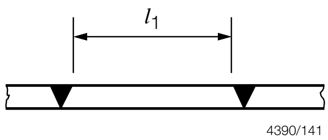
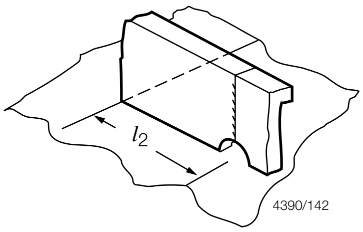
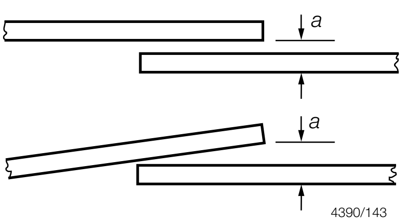
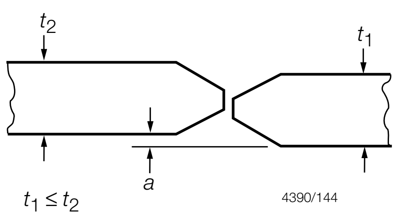
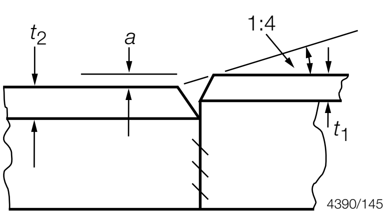
Joint	Location	Permitted misalignment	Remedial action	
	All areas (Continuous fillet weld)	a (mm) $a < 0{,}25t_1$ (max = 1 mm)	a (mm) $0{,}25t_1$ to $0{,}5t_1$ (t_1 max = 5 mm)	Increase weld leg length by ‘a’
			$0{,}5t_1$ to t_1 (t_1 max = 15 mm)	Vee material to +/–45°. Fit backing strip and weld. Remove backing strip and complete weld. 
			$a > t_1$	Realign and replace
	All areas (intermittent weld)	$< 0{,}25t_1$	$0{,}25$ to $0{,}5t_1$ (t_1 max = 3 mm) $0{,}25t_1$ to $0{,}5t_1$ (t_1 max = 5 mm)	Increase weld lengths by 50% Continuous weld
			$a > t_1$	As for continuous weld above
	Strength members Others Higher tensile steel joint in designated critical areas	$a \le t_2/3$ $a \le t_2/2$ $a \le t_3/3$	$t_2/3 \le a \le t_1/2$ $a > t_2/2$ $a > t_3/3$	Increase weld leg length of welds by 10% Realign Realign
	Strength members Others	$a \le 0{,}15t_1$ (max 3,0 mm) $a \le 0{,}2t_1$ (max 3,0 mm)	$a > 0{,}15t_1$ $a > 0{,}2t_1$	Realign Realign
	All areas	a in accordance with weld procedure	$a \le t_1$ $a > t_1$ (max 10 mm)	Build one side of butt until a in accordance with weld procedure Cut back 150 mm and fit insert plate

Table 1.8.5 Structural misalignment and fit (steel and aluminium)

Joint	Location	Acceptable dimensions (mm)	Remedial action	
	All	$l_1 \geq 40$ mm	—	Adjust to suit
	All	$l_2 \geq 20$ mm	—	Adjust to suit
	All	$l_1 > 50$ mm	$l_1 < 30$ mm	Treat as an insert
	All	$l_2 \geq 20$ mm	$l_2 < 15$ mm	Adjust to suit
	All All	$a \leq 1{,}0$ $a \leq 1{,}0$	$a < 5$ $a \leq 5$	Increase weld leg length by actual 'a' Adjust to suit
	Strength members Other	$a \leq 0{,}15t_1$ (max 3,0 mm) $a \leq 0{,}2t_1$ (max 3,0 mm)	$a > 0{,}15t_1$ $a > 0{,}2t_1$	Reject Reject
	All	For angle or tee longitudinal $a \leq 0{,}2t_1$ For offset bulb longitudinal $a \leq 0{,}2t_2$	$a > 0{,}2t_1$ $a > 0{,}2t_2$	Reject Reject

8.7 Post welding plate deformation

8.7.1 Post welding plate deformation for steel and aluminium alloy construction is to be limited, *see* Table 1.8.6 and Fig. 1.8.1.

Table 1.8.6 Plate deformation limits

Position	s/t	δ_p/s
in 0,6L amidship	≤ 80 > 80	1/100 1/75
Remainder	all	1/50

Where
s = stiffener spacing, in mm
t = plating thickness, in mm
δ_p = panel deflection, in mm

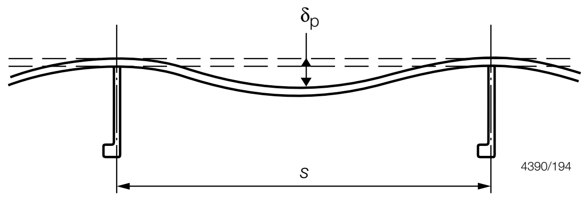


Fig. 1.8.1 Measurement of plate deformation

8.7.2 Deformation outside the limits of Fig. 1.8.1 is to be faired by local heating or the plating renewed.

8.7.3 Local heating of steel is not to exceed 900°C (red heat) when flame straightening is employed.

8.7.4 Local heating of aluminium alloys is not to be carried out. All repairs are to be by renewal of plating.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter illustrates the general principles to be adopted in applying the structural requirements given in Parts 4, 6, 7 and 8. In particular, consideration has been given to the layout of the Rules as regards the different regions of the craft, principles for taper of hull scantlings, definition of span point, derivation of section moduli and basic design loading for deck structures. Principles for subdivision are also covered.

1.1.2 Where additional requirements relating to particular craft types apply, these requirements are indicated in the appropriate Parts and are to be complied with as necessary.

■ *Section 2* Rule structural concept

2.1 General

2.1.1 The Rules are based on the concept that the structural and watertight integrity and general safe operation of the craft will not be compromised by static and dynamic loads experienced during normal operating conditions.

2.2 Scantlings

2.2.1 Scantlings are generally based on the strength required to withstand loads imposed by the sea, cargo, passengers, ballast, bunkers and other operational loads. However, the Rules assume that the nature and stowage of the cargo, ballast, etc., are such as to avoid excessive structural stress.

2.2.2 Design loads and pressures as given in Part 5, are to be used with scantling formulae or direct calculation methods to derive scantlings based on maximum allowable stress or other suitable strength criteria.

2.2.3 Hull structural vibration resulting from cyclic loadings arising from the sea and other sources are to be such that the normal operation and structural integrity of the craft are not impaired. However these aspects are outwith the scope of classification, *see* Pt 1, Ch 2,1.4.

2.3 Definition of requirements

2.3.1 Static loads are based on standard conditions defined in Part 5, or determined from loading conditions submitted by the Builder.

2.3.2 Dynamic loadings are examined for both the local and global structures. These loadings are based upon the designer's stated operational and environmental conditions or the Rule minimum criteria, whichever is the greater.

2.3.3 Wave induced loads are considered both in the static condition, i.e. hydrostatic and pitching pressures, and in the dynamic mode, i.e. impact, slamming and hogging and sagging wave landing conditions.

2.3.4 Hull girder strength will in general require to be investigated dependent upon the length, configuration, proportions, proposed loadings, etc., of the craft.

2.3.5 Scantling requirements in respect of miscellaneous items of structure such as local foundations, base plates, insert plates, etc., are not specifically indicated within these Rules. However the acceptance of such items will be specially considered on the basis of experience, good practice and direct calculation where appropriate.

2.4 Definitions and structural terms

2.4.1 The various definitions and structural terms for use throughout this Chapter are as indicated within the appropriate Section.

2.5 Symbols

2.5.1 The various symbols for use throughout this Chapter are as indicated within the appropriate Section.

Section 3 Structural idealisation

3.1 General

3.1.1 The scantling formulae in the Rules are normally based on elastic or plastic theory using simple beam models supported at one or more points and with varying degrees of fixity at the ends, in association with an appropriate concentrated or distributed load for steel and aluminium craft.

3.1.2 Apart from a local requirement for web or flange thicknesses, the stiffener, beam or girder strength is defined by a section modulus and moment of inertia requirement.

3.1.3 For the derivation of scantlings for fibre composite structures, the formulae are based on equivalent load carrying capability, with limitations on both allowable stress and strain, in addition to deflection controls.

3.2 Geometric properties of sections

3.2.1 The symbols used in this sub-Section are defined as follows:

b = the actual width, in metres, of the load-bearing plating, i.e. one-half of the sum of spacings between parallel adjacent members or equivalent supports

f = $0{,}3 \left(\dfrac{l}{b}\right)^{2/3}$

but is not to exceed 1,0. Values of this factor are given in Table 2.3.1

l = the overall length, in metres, of the primary support member, as indicated in Fig. 3.1.2 in Pt 6, Ch 3 and Pt 7, Ch 3, respectively, for steel and aluminium alloy construction and Fig. 3.1.4 of Pt 8, Ch 3 for composite construction

t_p = the thickness, in mm, of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

Table 2.3.1 Values of factor *f*

$\dfrac{l}{b}$	f	$\dfrac{l}{b}$	f
0,5	0,19	3,5	0,69
1,0	0,30	4,0	0,76
1,5	0,39	4,5	0,82
2,0	0,48	5,0	0,88
2,5	0,55	5,5	0,94
3,0	0,62	6,0 and above	1,00

NOTE
Intermediate values to be obtained by linear interpolation.

3.2.2 The effective geometric properties of rolled or built sections may be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the attached plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

3.2.3 The geometric properties of rolled or built stiffener sections and of swedges are to be calculated in association with effective area of attached load bearing plating of thickness, t_p, mm and of width as given by Pt 6, Ch 3,1.10 or Pt 7, Ch 3,1.11 for steel and aluminium alloy construction respectively. In no case, however, is the width of plating to be taken as greater than either the spacing of the stiffeners or the width of the flat plating between swedges, whichever is appropriate. The thickness, t_p, is the actual thickness of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

3.2.4 The effective section modulus of a corrugation over a spacing, s_c, is to be calculated from the dimensions and, for symmetrical corrugations, may be taken as:

$$z = \frac{d_w\,(3b\,t_p + c\,t_w)}{6000} \text{ cm}^3$$

where

d_w, b, t_p, c and t_w are measured, in mm, and are as shown in Fig. 2.3.1. The value of b is to be taken not greater than:

$50 t_p \sqrt{\dfrac{235}{\sigma_0}}$ for welded corrugations

$60 t_p \sqrt{\dfrac{235}{\sigma_0}}$ for cold formed corrugations

where

σ_0 is defined in Ch 3,1.2.

The value of θ is not to be taken less than 40°. The moment of inertia is to be calculated from:

$$I = 0{,}05 d_w Z \text{ cm}^4$$

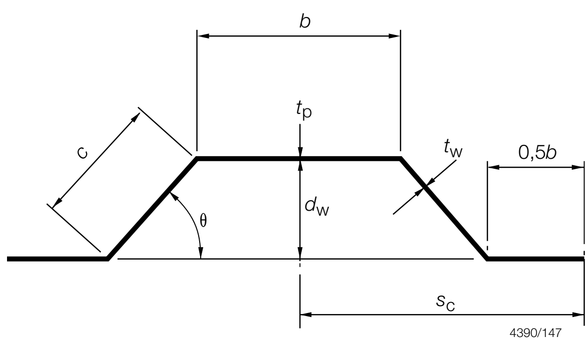


Fig. 2.3.1 Corrugation

3.2.5 The section modulus of a double plate bulkhead over a spacing, *b*, may be calculated as:

$$Z = \frac{d_w\,(6f\,b\,t_p + d_w\,t_w)}{6000} \text{ cm}^3$$

where

d_w, b, t_p and t_w are measured, in mm, and are as shown in Fig. 2.3.2.

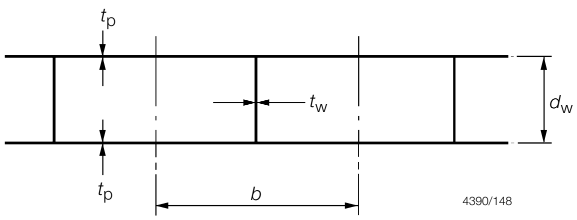


Fig. 2.3.2 Double plate bulkhead

3.2.6 The effective section modulus of a fabricated section may be taken as:

$$Z = \frac{a\,d_w}{10} + \frac{t_w\,d_w^2}{6000}\left(1 + \frac{200\,(A - a)}{200A + t_w\,d_w}\right) \text{cm}^3$$

where

a = the area of the face plate of the member, in cm^2

d_w = the depth, in mm, of the web between the inside of the face plate and the attached plating. Where the member is at right angles to a line of corrugations, the minimum depth is to be taken

t_w = the thickness of the web of the section, in mm

A = the area, in cm^2, of the attached plating, *see* 3.2.7 If the calculated value of A is less than the face area, a, then A is to be taken as equal to a.

3.2.7 The geometric properties of primary support members (i.e. girders, transverses, webs, stringers, etc.) are to be calculated in association with an effective area of attached load bearing plating, A, determined as follows:

(a) For a member attached to plane plating:
$A = 10f\,b\,t_p$ cm^2

where

f is as defined in 3.2.1.

(b) For a member attached to corrugated plating and parallel to the corrugations:
$A = 10b\,t_p$ cm^2
(*See* Fig. 2.3.1)

(c) For a member attached to corrugated plating and at right angles to the corrugations:
A is to be taken as equivalent to the area of the face plate of the member.

3.3 Determination of span point

3.3.1 The effective span, l_e, of a stiffening member is to be as defined in Parts 6, 7 and 8, for steel, aluminium alloy and composite construction respectively.

3.4 Calculation of hull section properties

3.4.1 The particular requirements for the calculation of the hull section modulus for craft of steel and aluminium alloy construction are defined in Pt 6, Ch 6 and Pt 7, Ch 6 respectively. The particular requirements for the hull section stiffness for craft of composite construction are defined in Pt 8, Ch 6.

■ *Section 4*
Bulkhead arrangements

4.1 General

4.1.1 Watertight bulkheads are, in general, to extend to the uppermost continuous watertight deck, hereinafter referred to as the bulkhead deck, and their construction is to be in accordance with Parts 6, 7 and 8 as appropriate.

4.1.2 Where openings are permitted in bulkheads they are to be provided with suitable closing devices in accordance with Ch 4,2.

4.2 Number and disposition of bulkheads

4.2.1 All craft with a Rule length, L_R, greater than 15 m are to have a collision bulkhead.

4.2.2 In motor craft with a Rule length, L_R, less than or equal to 15 m, the machinery is to be enclosed by gastight bulkheads to protect accommodation spaces from gas and vapour fumes from machinery, exhaust and fuel systems.

4.2.3 In all craft with a Rule length, L_R, less than or equal to 25 m, the sterntube is to be enclosed in a watertight compartment, wherever practicable.

4.2.4 All craft with a Rule length, L_R, greater than 25 m are to have an aft peak bulkhead, generally enclosing the sterntubes in a watertight compartment.

4.2.5 All craft with a Rule length, L_R, greater than 15 m are to have a watertight bulkhead at each end of the machinery space, where the machinery is amidships or a watertight bulkhead at the forward end of the machinery space, where the machinery is aft.

4.2.6 All craft with a Rule length, L_R, greater than 25 m are to have a watertight bulkhead at each end of the machinery space, with the aft peak bulkhead forming the aft bulkhead of the machinery space, where the machinery is aft.

4.2.7 Additional watertight bulkheads are to be fitted so that the total number of bulkheads is at least in accordance with Table 2.4.1.

Table 2.4.1 Total number of bulkheads

Length, L_R, in metres	Total number of bulkheads	
	Machinery amidships	Machinery aft
> 15 ≤ 25	3	2
> 25 ≤ 65	4	3*
> 65 ≤ 85	4	4*
> 85 ≤ 90	5	5*
> 90 ≤ 105	5	5*
> 105 ≤ 115	6	5*
> 115 ≤ 125	6	6*
> 125 ≤ 145	7	6*
> 145	To be individually considered	
*With afterpeak bulkhead forming after boundary of machinery space		

4.2.8 Bulkheads are to be spaced at reasonably uniform intervals. Where non-uniform spacing is unavoidable and the length of a compartment is unusually great, the transverse strength of the craft is to be maintained by fitting of web frames, increased framing, etc., and details are to be submitted.

4.2.9 Proposals to dispense with one or more of these bulkheads will be considered, subject to suitable structural compensation, if they interfere with the requirements of a special trade.

4.2.10 Where applicable, the number and disposition of bulkheads are to be arranged to suit the requirements for subdivision, floodability and damage stability, and are to be in accordance with the requirements of the National Authority.

4.3 Collision bulkhead

4.3.1 The collision bulkhead in all craft other than passenger craft, patrol craft and yachts is to be positioned as detailed in Table 2.4.2. Consideration will, however, be given to proposals for the collision bulkhead to be positioned slightly further aft on Arrangement (b) craft, but not more than $0{,}08L_L$ from the fore end of L_L, provided that the application is accompanied by calculations showing that flooding of the space forward of the collision bulkhead will not result in any part of the freeboard deck becoming submerged, or any unacceptable loss of stability. Special consideration may be given to the extent of the collision bulkhead above the bulkhead deck for multi-hull craft.

4.3.2 The collision bulkhead in passenger craft, patrol craft and yachts is to be in accordance with the following:

(a) A craft shall have a forepeak or collision bulkhead, which shall be watertight up to the bulkhead deck. (The bulkhead deck is the uppermost deck up to which the transverse watertight bulkheads are carried, *see* 4.2.10). This bulkhead is to be positioned as detailed in Table 2.4.3.

Table 2.4.2 Collision bulkhead position (excluding passenger craft, patrol craft and yachts)

Arrangement	Length, L_L	Distance of collision bulkhead aft of the fore end of L_L, in metres	
		Minimum	Maximum
(a)	≤ 150	$0{,}05L_L$	$0{,}08L_L$
(b)	≤ 150	$0{,}05L_L - f_1$	$0{,}08L_L - f_1$

Symbols and definitions

$f_1 = \frac{G}{2}$ or $0{,}015L_L$, whichever is the lesser

G = projection of bulbous bow forward of fore end of L_L, in metres

L_L is as defined in Ch 1,6.2

Arrangement (a) A craft that has no part of its underwater body extending forward of the fore end of L_L

Arrangement (b) A craft with part of its underwater body extending forward of the fore end of L_L (e.g. bulbous bow)

(b) If the craft has a long forward superstructure, the forepeak or collision bulkhead is to be extended weathertight to the deck next above the bulkhead deck. The extension need not be fitted directly over the bulkhead below, provided it is located within the limits specified in Table 2.4.3 with the exemption permitted by 4.6.3 and the part of the bulkhead deck which forms the step is made effectively weathertight.

4.3.3 Alternative arrangements may be submitted for consideration in the case of sailing and auxiliary craft.

4.3.4 For craft with pronounced rake of stem, the position of the collision bulkhead will be specially considered.

4.3.5 Accesses are not to be fitted in collision bulkheads. In particular designs where it would be impracticable to arrange access to the fore peak other than through the collision bulkhead, access may be permitted subject to special consideration. Where accesses are provided, the openings are to be as small as practicable and positioned as far above the design waterline as possible. The closing appliances are to be watertight, to open into the fore peak compartment and consideration will be given to operation from one side only.

4.4 Aft peak bulkhead

4.4.1 An aft peak bulkhead, where required to be fitted (in each half of a multi-hull craft) is, in general, to enclose the sterntube, water jet unit, etc., in a watertight compartment. In twin screw craft the sterntubes are to be enclosed in suitable watertight spaces. *See also* Table 2.4.1.

Table 2.4.3 Collision bulkhead for passenger craft, patrol craft and yachts

Arrangement	Distance of collision bulkhead aft of fore perpendicular, in metres	
	Minimum	Maximum
(a)	$0,05L_{pp}$	$3 + 0,05L_{pp}$
(b)	$0,05L_{pp} - f$	$3 + 0,05L_{pp} - f$
Symbols and definitions		
$f = \frac{G}{2}$ or $0,015L_{pp}$, whichever is the lesser G = projection of bulbous bow forward of fore perpendicular, in metres L_{pp} is as defined in Ch 1, 6.2 Arrangement (a) A craft that has no part of its underwater body extending forward of the fore perpendicular. Arrangement (b) A craft with part of its underwater body extending forward of the fore perpendicular, e.g. bulbous bow.		

4.5 Height of bulkhead

4.5.1 The collision bulkhead is normally to extend to the uppermost continuous deck or, in the case of craft with combined bridge and forecastle or a long superstructure which includes a forecastle, to the superstructure deck. However, if a craft is fitted with more than one complete superstructure deck, the collision bulkhead may be terminated at the deck next above the freeboard deck. Where the collision bulkhead extends above the freeboard deck, the extension need only be to weathertight standards.

4.5.2 The aft peak bulkhead may terminate at the first deck above the load waterline, provided that this deck is made watertight to the stern or to a watertight transom floor. In passenger craft the aft peak bulkhead is to extend watertight to the bulkhead deck. However, it may be stepped below the bulkhead deck provided the degree of safety of the craft as regards watertight subdivision is not thereby diminished.

4.5.3 The remaining watertight bulkheads are to extend to the bulkhead deck. In passenger craft of restricted draught and all craft of unusual design, the height of the bulkheads will be specially considered.

4.6 Watertight recesses, flats and loading ramps

4.6.1 Watertight recesses in bulkheads are generally to be so framed and stiffened as to provide strength and stiffness equivalent to the requirements for watertight bulkheads.

4.6.2 In collision bulkheads, any recesses or steps in the bulkhead are to fall within the limits of bulkhead positions given in 4.3.1 or 4.3.3 as applicable. Where the bulkhead is extended above the freeboard deck, or bulkhead deck in passenger craft, the extension need only be to weathertight standards. If a step occurs at that deck, the deck need also only be to weathertight standards in way of the step, unless the step forms the crown of a tank, in which case the requirements for deep tank structures are to be complied with.

4.6.3 In craft fitted with bow doors, in which a sloping loading ramp forms part of the collision bulkhead above the freeboard or bulkhead deck, that part of the ramp which is more than 2,30 m above the freeboard or bulkhead deck may extend forward of the minimum limit specified in Table 2.4.2 or Table 2.4.3 as appropriate. Such a ramp is to be weathertight over its complete length.

4.7 Gastight bulkheads

4.7.1 Where bulkheads are required to be gastight in accordance with 4.2.2, and where it is proposed to pierce such bulkheads for the passage of cables, pipes, vent trunking, etc., gastight glands are to be provided to maintain the gastight integrity.

4.8 Tank bulkheads

4.8.1 The scantlings of deep tank bulkheads are to be in accordance with Ch 3,7 of Parts 6, 7 and 8, for steel, aluminium alloy and composite structures respectively.

4.8.2 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side of the craft. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to be as required for boundary bulkheads. If perforated, the modulus of stiffeners may be 50 per cent of that required for boundary bulkheads, using a head measured to the crown of the tank.

4.8.3 The arm length of brackets at the ends of the stiffeners is to be 2,5 times the depth of stiffener. The thickness of the brackets is to be not less than the web thickness of the stiffener.

4.8.4 Air and sounding pipes are to comply with the requirements of Pt 15, Ch 2,11.

4.9 Cofferdams

4.9.1 Tanks carrying oil fuel or lubricating oil are to be separated by cofferdams from those carrying feed water, fresh water, edible oil or similar oils. Similarly tanks carrying vegetable or similar oils are to be separated by cofferdams from those carrying fresh or feed water. Cofferdams are to be fitted between freshwater tanks and black or grey water tanks.

4.9.2 Lubricating oil tanks are also to be separated by cofferdams from those carrying oil fuel. However such cofferdams need not be fitted provided that:

(a) Common boundaries of lubricating oil and oil fuel tanks have full penetration welds.
(b) The tanks are arranged such that the oil fuel tanks are not generally subjected to a head of oil in excess of that in the adjacent lubricating oil tanks.

4.9.3 Cofferdams are not required between oil fuel double bottom tanks and deep tanks above, provided that the inner bottom plating is not subjected to a head of oil fuel.

4.9.4 Where fitted, cofferdams are to be suitably ventilated.

4.9.5 If oil fuel tanks are necessarily located within or adjacent to the machinery spaces, their arrangement is to be such as to avoid direct exposure of the bottom from rising heat resulting from an engine room fire. *See* Part 17 as applicable.

4.9.6 In passenger craft, water ballast is, in general, not to be carried in tanks intended for oil fuel. Attention is drawn to the Statutory Regulations issued by National Authorities in connection with the *International Convention for the Prevention of Pollution of the Sea by Oil, 1973/78.*

4.10 Means of escape

4.10.1 For the requirements for means of escape on service craft and yachts over 24 m in length, *see* Pt 17, Ch 2 and Pt 17, Ch 3 respectively.

4.10.2 The arrangement of the hull is to be such that all underdeck compartments are as accessible as practicable and provided with a satisfactory means of escape. Access and escape hatches to the machinery and tanks are not to be obstructed by deck coverings or furniture.

4.11 Carriage of low flash point fuels

4.11.1 Special provision is to be made for the carriage of low flash point fuel in accordance with Pt 15, Ch 3,5.

■ *Section 5* Fore and aft end arrangements

5.1 General

5.1.1 The requirements in respect of the general constructional arrangements for mono-hull craft covered by the Rules are contained within this Section.

5.2 Structural configuration

5.2.1 The Rules provide for both longitudinal and transverse framing systems.

5.3 Structural continuity

5.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

5.3.2 Where longitudinal framing terminates and is replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover. Where a forecastle is fitted extending aft of 0,15L from the F.P., longitudinal framing at the upper deck and topsides is generally to be continued forward of the end bulkhead of this superstructure.

5.4 Minimum bow height and reserve buoyancy

5.4.1 All sea-going craft are to be fitted with forecastles, or increased sheer on the upper deck or equivalent, such that the distance from the summer load waterline to the top of the exposed deck at side at the F.P. is not less than:

$$H_b = \left(6075\left(\frac{L_L}{100}\right) - 1875\left(\frac{L_L}{100}\right)^2 + 200\left(\frac{L_L}{100}\right)^3\right) \times \left(2{,}08 + 0{,}609C_b - 1{,}603C_{wf} - 0{,}0129\left(\frac{L_L}{d_1}\right)\right)$$

where

d_1 = draught at 85 per cent of the depth D, in metres

A_{wf} = waterplane area forward of $\frac{L_L}{2}$ at draught d_1, in m^2

B = moulded breadth, in metres

C_b = block coefficient as defined in the Load Lines Convention

C_{wf} = the waterplane area coefficient forward of

$$C_{wf} = \frac{A_{wf}}{\left(\frac{L_L}{2}\right) \times B}$$

H_b = minimum bow height

L_L = Load Line length, in metres.

5.4.2 Craft which are designed to suit exceptional operational requirements, restricted in their service to Group G1, or of novel configuration will be specially considered on the basis of the Rules.

5.4.3 Where the bow height required in 5.4.1 is obtained by sheer, the sheer shall extend for at least 15 per cent of the length of the craft measured abaft the forward end of L_L. Where it is obtained by fitting a forecastle, the forecastle shall extend from the stem to a point at least 0,07L_L abaft the forward end of L_L, and shall be enclosed.

5.4.4 Craft shall have additional reserve buoyancy in the fore end in accordance with the Load Lines Convention.

5.5 Bow crumple zone

5.5.1 In general, the bow crumple zone is that space forward of the collision bulkhead. Passenger and crew accommodation and the carriage of fuel and other oils is not permitted in the bow crumple zone.

5.6 Strengthening of bottom forward

5.6.1 Except for craft with **G1** and **G2** service notations, additional strengthening of bottom forward is required for craft with the rule length, L_R, greater than 65 m. Details are to be submitted for consideration.

5.7 Bulbous bows

5.7.1 Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure.

5.7.2 At the fore end of the bulb the structure is generally to be supported by horizontal diaphragm plates spaced generally 1,0 m apart in conjunction with a deep centreline web.

5.7.3 In general, vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing.

5.7.4 In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is generally to be fitted.

5.7.5 In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or substantial web frames spaced about five frame spaces apart are generally to be fitted.

5.7.6 The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness is to be the same as that required for plated stems.

5.8 Strengthening against bow flare slamming

5.8.1 Where a craft has pronounced flare or rake of bow, the structure in the forward region will be subject to special consideration, and the scantlings and arrangements may require additional strengthening.

■ *Section 6* Machinery space arrangements

6.1 General

6.1.1 This Section applies to all craft types. Only requirements particular to machinery spaces, including protected machinery casings and engine seatings, are given. For other scantlings and arrangement requirements, *see* the relevant Chapter in Parts 6, 7 and 8.

6.2 Structural configuration

6.2.1 Requirements are given for craft constructed using either a transverse or longitudinal framing system, or a combination of the two.

6.2.2 For machinery spaces situated aft, where the longitudinal framing terminates and is replaced by transverse framing, a suitable scarfing arrangement of the longitudinal framing is to be arranged. *See also* 5.3.

6.2.3 The maximum spacing, S_{max}, of web frames in longitudinally framed machinery spaces is not to exceed 3,8 m. Additionally for transversely framed craft, in way of a machinery space situated adjacent to the aft peak, the spacing of web frames is not to exceed six transverse frame spaces.

6.2.4 Where the machinery space is situated in the midship region, it is recommended that web frames be fitted in the engineroom, spaced not more than six frame spaces apart and extending from the tank top to the level of the lowest deck above the load waterline. The scantlings of these webs are to be such that the combined section modulus of the web frame and the main or ‘tween deck frames is 50 per cent greater than that required for normal transverse framing. These webs may be omitted if the section modulus of the transverse frames is increased by 50 per cent.

6.3 Structural continuity

6.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt discontinuities where structure which contributes to the main longitudinal strength of the craft is omitted in way of a machinery space.

6.4 Deck structure

6.4.1 The corners of machinery space openings are to be of suitable shape and design to minimize stress concentrations.

6.4.2 In motor craft having a Rule length, L_R, less than 15 m, the machinery is to be enclosed by gastight decks to protect accommodation spaces from gas and vapour fumes from machinery, exhaust and fuel systems.

6.5 Side shell structure

6.5.1 Side shell structure is to be constructed in accordance with the scantlings indicated in Parts 6, 7 and 8, for steel, aluminium alloy and composite structures respectively.

6.5.2 General requirements for web frames are given in this Section for both longitudinal and transverse framing systems. Where longitudinal framing is adopted in the midship region it is to be carried as far forward and aft as practicable.

6.5.3 A transverse framing system is to be additionally reinforced by web frames fitted six frame spaces apart. Where a longitudinal framing system is adopted, the spacing of the transverses is not to exceed 2,5 m.

6.6 Double and single bottom structure

6.6.1 Where the Rule length, L_R, of the craft exceeds 50 m, a double bottom is to be fitted in the hull (or hulls in multi-hull craft), extending from the collision bulkhead to the forward watertight bulkhead for the machinery space.

6.6.2 Where the Rule length, L_R, of the craft exceeds 61 m, a double bottom is to be fitted outside the machinery space and is to extend to the collision bulkhead and the aft peak bulkhead. Where no aft peak bulkhead is fitted, the extent of the double bottom will be specially considered.

6.6.3 Where the Rule length, L_R, of the craft exceeds 76 m, the double bottom is to extend throughout the length of the craft.

6.6.4 For multi-hull craft and other craft which are to be assigned an **HSC** notation or which are to operate within **Restricted Service Groups G1**, **G2** and **G3**, the extent of the double bottom will be specially considered depending on the number of transverse watertight bulkheads and the requirements of the National Authority concerning stability after damage.

6.6.5 Margin plates and drainage wells are to be provided as necessary and subject to special consideration.

6.6.6 The scantlings of bottom stiffening, floors, centre girders and side girders are to be in accordance with the appropriate Sections of Parts 6, 7 and 8 of the Rules, for craft built in steel, aluminium alloy and composite respectively.

6.6.7 In motor craft the thickness of the floors in machinery spaces is to be 1mm greater than that required by the appropriate Sections of Parts 6 and 7 of the Rules, for craft built in steel and aluminium alloy respectively.

6.6.8 In craft having considerable rise of floor, the depth of the floor plate, or its height at side, may require to be increased. The transverse extent of double bottom will be specially considered.

6.6.9 Suitable arrangements are to be made to provide free passage of water from all parts of the bilge to the pump suctions.

6.6.10 A centreline girder is to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m. Where the breadth of the floors at the upper edge exceeds 6,0 m a side girder is also to be fitted each side of the centre girder.

6.6.11 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity.

6.6.12 Centreline girders fitted in association with flat plate keels are to be formed of intercostal or continuous plates with a continuous face flat welded on the upper edge.

6.6.13 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with 6.8.

6.7 Machinery casings

6.7.1 The scantlings and arrangements of exposed casings protecting machinery openings are to be in accordance with Ch 3,9.8, of Parts 6 and 7, for craft built in steel and aluminium alloy respectively.

6.7.2 Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably increased. *See also* Ch 3,10, Parts 6, 7 and 8, for craft built in steel, aluminium alloy and composite respectively.

6.7.3 Where casing sides act as girders supporting decks over, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular care is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

6.7.4 Casing bulkheads are to be made gastight and the access doors are to be of a gastight self-closing type.

6.8 Integral fuel tanks

6.8.1 The scantlings of deep tank bulkheads are to be in accordance with Ch 3,7, of Parts 6, 7 and 8, for craft built in steel, aluminium alloy and composite respectively.

6.9 Machinery seatings

6.9.1 Main and auxiliary engines in motor and auxiliary sailing craft are to be effectively secured to the hull structure by seatings of adequate scantlings to resist the gravitational, thrust, torque and vibrating forces which may be imposed upon them.

6.9.2 The longitudinal girders forming the engine seatings are to extend as far forward and aft as practicable and be adequately supported by transverse floors or brackets.

6.9.3 In determining the scantlings of seats for oil engines, consideration is to be given to the general rigidity of the engine itself and to its design characteristics with regard to out of balance forces.

6.9.4 The seats are to be so designed that they distribute the forces from the engine(s) as uniformly as possible into the supporting structure. Longitudinal girders supporting the seatings are to be arranged in single or double bottoms, and are, in general to extend over the full length of the machinery space. The ends of the girders are to be scarfed into the bottom structure for at least two frame spaces. Adequate transverse brackets are to be arranged in line with floors. Small brackets may be required under the top plate in way of holding down bolts.

6.9.5 For gas turbine installations, seats are to be so designed as to provide effective support and ensure their proper alignment with the gearing, and where applicable allow for thermal expansion of the casings. In general, the seats are not to be arranged in way of breaks or recesses in the double bottom.

6.9.6 Auxiliary machinery is to be secured on seatings, of adequate scantlings, so arranged as to distribute the loadings evenly into the supporting structure.

6.10 Thrust blocks

6.10.1 Main engines and thrust bearings are to be effectively secured to the hull structure by seatings of adequate scantlings to resist the various gravitational, thrust, torque, dynamic and vibratory forces which may be imposed on them.

6.10.2 For initial guidance, it is recommended that the scantlings for oil engine seatings be as indicated in 6.9.3.

■ *Section 7* Superstructures, deckhouses and bulwarks

7.1 General

7.1.1 Superstructures, deckhouses and bulwarks are to be constructed in accordance with the scantlings indicated in Ch 3,9 of Parts 6, 7 and 8, for steel, aluminium alloy and composite structures respectively.

7.2 Definition of tiers

7.2.1 The lowest, or first tier, is normally that which is directly situated on the deck to which *D* is measured. The second tier is the next tier above the lowest tier and so on. *See* Fig. 2.7.1.

7.2.2 Where the vertical distance between the weatherdeck and the summer load waterline is equal to or greater than the sum of the minimum freeboard and one standard superstructure height, then proposals to treat the first tier erection as a second tier, and so on, will be specially considered. The standard height of superstructure is the height defined in Ch 1,6.13.3. *See* Fig. 2.7.1.

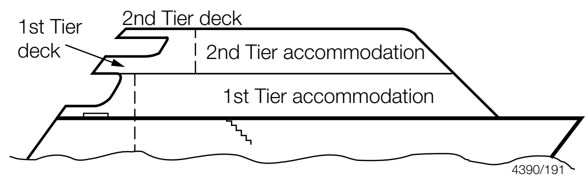


Fig. 2.7.1 Definition of tiers

7.2.3 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

7.3 Unusual designs

7.3.1 Craft or structural arrangements which are of unusual design, form or proportions will be individually considered. Special features will be considered in each separate case.

■ *Section 8* Particular requirements for multi-hulls

8.1 General

8.1.1 The requirements indicated in this Section are particular to multi-hull craft and are to be applied in addition to the general requirements of this Chapter.

8.1.2 The craft is to be considered as one complete structure when determining the minimum geometric summer freeboard. The block coefficient is to be calculated using the actual displacement determined from the hydrostatic data and using the total breadth of the structure and not just a single hull.

8.1.3 If, by using normal procedures, the minimum geometric summer freeboard determined is unreasonable for the operation of the craft, special consideration may be given, on a case by case basis, based on the proposed design configuration.

8.2 Structural configuration

8.2.1 The scantlings and arrangements indicated are for twin hulled craft. Craft with a greater number of hulls will be specially considered on the basis of the Rules.

8.3 Structural continuity

8.3.1 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performances.

8.3.2 Particular care is to be given to the continuity and alignment in way of the end connections of transverse bridging structures.

8.4 Cross-deck structure

8.4.1 For craft with multi-hulls linked by cross-deck structures, sufficient clearance is to be provided between the cross-deck structure and water surface to limit impact loads.

8.4.2 Where part or all of the cross-deck is intended to provide additional buoyancy to limit craft motion, the loading will be specially considered.

8.4.3 In the determination of the clearance, the following factors should be considered:
(a) Relative motion in waves.
(b) The wave generated between the hulls when running.
(c) The bow sinkage.

8.4.4 The submitted clearances must be validated either by calculations according to accepted theories, model test, full scale measurements or by documentary evidence if similar structures have proved to be satisfactory in service.

8.4.5 Where it is not possible to provide sufficient clearance to reduce the likelihood of slamming of the cross-deck structure, direct calculations or other appropriate means are to be used to assess the loads, assuming the most severe conditions for which the craft is to be approved.

8.5 Bulkheads

8.5.1 Longitudinal watertight bulkheads are to be arranged within the bridging structures of multi-hull craft to prevent cross flooding and the spread of smoke and flames in the event of fire. The number and distribution of bulkheads will be specially considered dependent upon the structural configuration and size of the craft but in no case is the number to be less than two for catamarans and four for trimarans.These bulkheads are in general to be positioned in way of the inboard sides of the hulls.

8.6 Fore and aft ends

8.6.1 The forefoot and bow regions of fast craft that may be subjected to frequent impacts from flotsam are to be easily accessible for inspection. Access to the forepeak compartments may be provided through the forepeak bulkhead where access would otherwise be impracticable.

8.6.2 The aft end regions of all craft are to be easily accessible for inspections. Access may be provided through the aft peak bulkhead or by means of deck hatches or manholes.

8.7 Machinery spaces

8.7.1 Where an engine is fitted within a narrow hull, where engineroom temperatures may rise quickly, the ventilation requirements may require to be increased.

8.7.2 Within machinery spaces where space is limited access is to be provided for inspection.

8.8 Superstructures, deckhouses and bulwarks

8.8.1 Superstructures and deckhouses which enclose large flat open areas, that are subjected to racking loads and which may be of several tiers, are to be additionally stiffened with large web frames, partial bulkheads and pillars.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all the craft types detailed in the Rules, and requirements are given for rudders, nozzles, steering gear, bow and stern thrust unit structure and stabilizer structure.

1.2 General

1.2.1 The following symbols and definitions are applicable to this Chapter, unless otherwise stated:

σ_o = minimum yield stress or 0,5 per cent proof stress of the material, in N/mm^2 and is not to be taken greater than 0,7σ_T

where

σ_T = ultimate tensile strength of the material, in N/mm^2.

1.2.2 The scantlings in aluminium alloy are to be obtained by multiplying the scantlings in mild steel, determined from this Chapter, by the following factors:

(a) Plating thickness factor = k_{ta}
where $k_{ta} = \sqrt{k_{aa}}$

(b) Section modulus and cross sectional area factor, k_{aa}
where

k_{aa} = 235/σ_{ya} or 1,36, whichever is the greater

σ_{ya} = specified minimum yield stress or 0,2 per cent proof stress of aluminium alloy in the welded condition, in N/mm^2.

1.3 Navigation in ice

1.3.1 Where an ice class notation is to be included in the class of a craft, the scantlings as determined from this Chapter will require to be specially considered. The additional requirements for operation in ice will, in general, be in accordance with Lloyd's Register's (hereinafter referred to as 'LR') *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), Pt 3, Ch 9, where appropriate, and also Ch 5,6 of Parts 6, 7 and 8, for steel, aluminium and composite construction respectively.

1.4 Materials

1.4.1 The requirements for materials are contained in the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

■ *Section 2* Rudders

2.1 General

2.1.1 The scantlings of the rudder stock are to be not less than those required by Table 3.2.7.

2.1.2 For rudders having an increased diameter of rudder stock, *see* Fig. 3.2.1, the increased diameter is to be maintained to a point as far as practicable above the top of the lowest bearing. This diameter may then be tapered to the diameter required in way of the tiller. The length of the taper is to be at least three times the reduction in diameter. Particular care is to be taken to avoid the formation of a notch at the upper end of the taper.

2.1.3 Sudden changes of section or sharp corners in way of the rudder coupling, jumping collars and shoulders for rudder carriers, are to be avoided.

2.2 Definition and symbols

2.2.1 Definitions and symbols for use throughout this Section are indicated in the appropriate tables.

2.3 Direct calculations

2.3.1 Where the rudder is of a novel design, high aspect ratio or the speed of the craft exceeds 45 knots the scantlings of the rudder and rudder stock are to be determined by direct calculation methods incorporating model test results and structural analysis, where considered necessary by LR.

2.4 Equivalents

2.4.1 Alternative methods of determining the loads will be specially considered, provided that they are based on model tests, full scale measurements or generally accepted theories. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

2.5 Rudder arrangements

2.5.1 Rudders considered are the types shown in Fig. 3.2.1, of double plate or single plate construction, constructed from steel, stainless steel or aluminium alloy. Other rudder types and materials will be subject to special consideration.

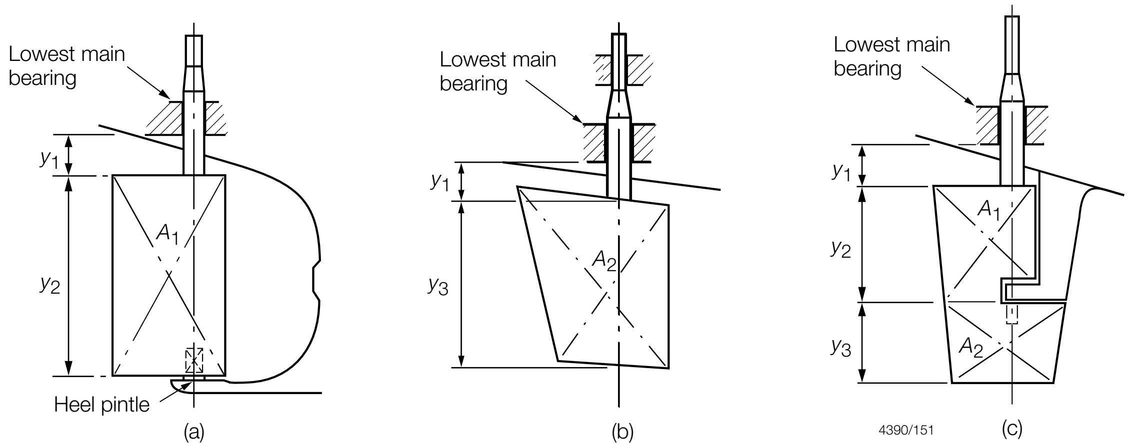


Fig. 3.2.1 Rudder types

2.6 Rudder profile coefficient f_R

2.6.1 The rudder profile coefficient f_R for use in Table 3.2.7 is to be as indicated in Table 3.2.1.

Table 3.2.1 Rudder profile coefficient f_R

Design criteria (*see* Fig. 3.2.2)	f_R ahead condition	f_R astern condition
Normal profile	1,0	0,97
Hollow profile	1,25	1,12
High lift profile	1,7	To be specially considered
Symbols		
f_R = rudder profile coefficient for use in Table 3.2.7		
NOTE Where a rudder is behind a fixed nozzle, the value of f_R given above, is to be multiplied by 1,3.		

2.7 Rudder angle coefficient f_θ

2.7.1 The rudder angle coefficient, f_θ, for use in Table 3.2.7 is to be as indicated in Table 3.2.2.

Table 3.2.2 Rudder angle coefficient f_θ

Rudder angle	2 x 35°	2 x 45°
f_θ	1,0	1,23
Symbols		
f_θ = rudder coefficient for use in Table 3.2.7. Intermediate values may be obtained by interpolation		

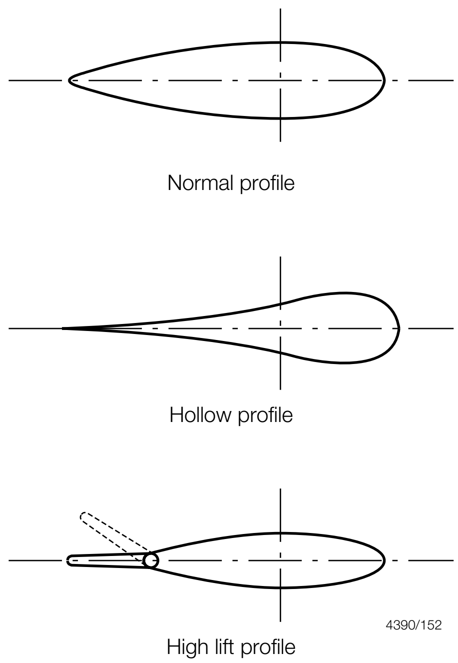


Fig. 3.2.2 Rudder profiles

2.8 Rudder position coefficient f_p

2.8.1 The rudder position coefficient, f_p, for use in Table 3.2.7 is to be as indicated in Table 3.2.3.

2.9 Rudder speed coefficient f_v

2.9.1 The rudder speed coefficient, f_v, for use in Table 3.2.7 is to be as indicated in Table 3.2.4.

Table 3.2.3 Rudder position coefficient f_p

Design criteria		f_p
Ahead condition	Rudder in propeller slipstream	0,248
	Rudder out of propeller slipstream	0,235
Astern condition		0,185
Bow rudder		0,226
Symbols		
f_p = rudder coefficient for use in Table 3.2.7		

Table 3.2.4 Rudder speed coefficient f_v

Design criteria	f_v
Craft with $\dfrac{V}{\sqrt{L_{WL}}} < 3,0$	1,00
Craft with $\dfrac{V}{\sqrt{L_{WL}}} \geq 3,0$	1,12 – 0,005V
Symbols	
L_{WL} as defined in Ch 1,6.2.5 V as defined in Table 3.2.7 f_v = rudder speed coefficient for use in Table 3.2.7	

2.10 Pintle arrangement coefficient *N*

2.10.1 The pintle arrangement coefficient, N, for use in Table 3.2.7 is to be as indicated in Table 3.2.5.

Table 3.2.5 Pintle arrangement coefficient *N*

Support arrangement	Value of N
Two or more pintles Upper stock	$N = 0$
One or no pintle	$N = A_1(0,67y_1 + 0,17y_2) - A_2(y_1 + 0,5y_3)$
Symbols	
N = coefficient for use in Table 3.2.7 A_1, A_2 = part rudder areas, in m^2, *see* Fig. 3.2.1 y_1, y_2, y_3 = vertical dimensions, in metres, *see* Fig. 3.2.1 Any values of y and A not indicated in Fig. 3.2.1 are to be taken as zero.	
NOTE If, in semi-spade (Mariner) type rudders, the pintle is housed above the rudder horn gudgeon and not as shown in Fig. 3.2.1(c), y_2 and y_3 are to be measured to the top of the gudgeon.	

2.11 Centre of pressure

2.11.1 The position of centre of pressure for use in Table 3.2.7 is to be as indicated in Table 3.2.6.

Table 3.2.6 Position of centre of pressure

Design criteria	Value of x_{PF} and x_{PA} to be used in Table 3.2.7
Rectangular rudders; (a) Ahead condition (b) Astern condition	x_{PF} = $(0,33ex_B - x_L)$, but not less than $0,12x_B$ x_{PA} = $(x_A - 0,25x_B)$, but not less than $0,12x_B$
Non-rectangular rudders; (a) Ahead condition (b) Astern condition	x_{PF}, x_{PA} as calculated from geometric form (*see* Note) but not less than: $\dfrac{0,12A_R}{y_R}$
Symbols	
x_{PF} = horizontal distance from the centreline of the rudder pintles, or axle, to the centre of pressure in the ahead condition, in metres x_{PA} = horizontal distance from the centreline of the rudder pintles, or axle, to the centre of pressure in the astern condition, in metres x_B = breadth of rudder, in metres y_R = depth of rudder at centreline of stock, in metres A_R = rudder area, in m^2 x_L and x_A = horizontal distances from leading and after edges, respectively, of the rudder to the centreline of the rudder pintles, or axle, in metres x_S = horizontal length of any rectangular strip of rudder geometric form, in metres e = hull form factor at ahead condition for $L < 65$ m, $e = 1,0$ for $L \geq 65$ m, $e = 2\left(C_b + 10\dfrac{B}{L_R} - 2\right)\dfrac{V}{\sqrt{L_R}}$ or $e = 1 + \left(\dfrac{L_R - 65}{70}\right)$ whichever is the lesser, but not less than 1,0 and need not be taken greater than 1,5 L_R, B and C_b are as defined Ch 1,6.2 V is as defined in Table 3.2.7	
NOTE For rectangular strips the centre of pressure is to be assumed to be located as follows: (a) $0,33ex_S$ abaft leading edge of strip for ahead condition. (b) $0,25x_S$ from aft edge of strip for astern condition.	

Table 3.2.7 Rudder stock diameter

Requirement
1. Basic stock diameter, d_s, at and below lowest bearing: $$d_s = f_c\, f_p\, f_v \sqrt[3]{\left(\frac{235}{\sigma_0}\right)^m f_R\, f_\theta\, (V+3)^2 \sqrt{A_R{}^2\, x_p{}^2 + N^2}}\ \text{mm}$$
2. Diameter in way of tiller, d_{SU}: $d_{SU} = d_s$ calculated from (1) with $N = 0$
3. Lateral force on rudder acting at centre of pressure of blade, P_L: $$P_L = \left(\frac{f_p}{0{,}248}\right)^3 \frac{(V+3)^2 A_R\, f_R\, f_\theta}{10}\ \text{kN}$$
Symbols
f_c = 79 for craft of Rule length, L_R, 50 m and below varying up to 83,3 at a Rule length, L_R, of 70 m. Intermediate values to be obtained by interpolation 83,3 for craft of Rule length, L_R, 70 m and above f_p = rudder position coefficient, *see* Table 3.2.3 f_v = rudder speed coefficient, *see* Table 3.2.4 f_R = rudder profile coefficient, *see* Table 3.2.1 f_θ = rudder angle coefficient, *see* Table 3.2.2 m = 0,75 for $\sigma_0 > 235$ = 1,0 for $\sigma_0 \leq 235$ σ_0 = minimum yield stress, in N/mm^2, of material used, and is not to be taken greater than $0{,}7\sigma_T$ σ_T = ultimate tensile strength of the material used, in N/mm^2 V = the maximum speed for the astern and ahead condition, in knots. In no case to be less than 5 knots A_R = rudder area, in m^2 x_P = x_{Pa} or x_{Pf}, for the astern and ahead condition respectively, *see* Table 3.2.6 N = coefficient dependent on rudder support arrangement, *see* Table 3.2.5
NOTE Where higher tensile steel is used for the rudder stock, σ_0 is not to be taken as greater than 450 N/mm^2.

2.12 Rudder stock (tubular)

2.12.1 Tubular rudder stock scantlings are to be not less than that necessary to provide the equivalent strength of a solid stock as required by Table 3.2.7, and can be calculated from the following formula:

$$d_E = \sqrt[3]{\frac{d_1{}^4 - d_2{}^4}{d_1}}\ \text{mm}$$

where

d_E = the diameter of the equivalent solid rudder stock, in mm

d_1, d_2 = external and internal diameters, respectively of the tubular stock, in mm.

2.13 Single plate rudders

2.13.1 The scantlings of a single plate rudder are to be not less than required by Table 3.2.8, *see also* 2.5.1.

Table 3.2.8 Single plate rudder construction

Item	Requirement
Blade thickness	$t_B = 0{,}0015V\, y_W + 2{,}5$ mm with a minimum of 10 mm
Arms	Spacing ≤ 1000 mm $Z_A = 0{,}0005V^2\, x_a{}^2\, y_W$ cm^3
Mainpiece	Diameter = d_s mm For spade rudders, the lower third may taper down to $0{,}75d_s$ mm
Symbols	
t_B = blade thickness, in mm y_W = vertical spacing of rudder arms, in mm V = maximum speed, in knots, as defined in Table 3.2.7 x_a = horizontal distance from the aft edge of the rudder to the centre of the rudder stock, in metres Z_A = section modulus of arm, in cm^3	

2.13.2 Rudder arms are to be efficiently attached to the mainpiece.

2.14 Double plate rudders

2.14.1 The scantlings of a double plated rudder are to be not less than required by Table 3.2.9.

2.14.2 In way of rudder couplings and heel pintles the plating thickness is to be suitably increased.

2.14.3 On semi-spade (Mariner) type rudders a notch effect in the corners in the bottom pintle region is to be avoided (*see* AA, Fig. 3.2.3). An insert plate, 1,6 times the Rule thickness of the side plating, is to be fitted at this position, extending aft of the main vertical web and having well rounded corners. The main vertical web is to be continuous over the full depth of the rudder and have a thickness not less than three times the thickness required by Table 3.2.9, Item (5). Where an additional continuous main vertical web is arranged to form an efficient box structure, the webs are to have a thickness not less than required by Table 3.2.9, Item (5).

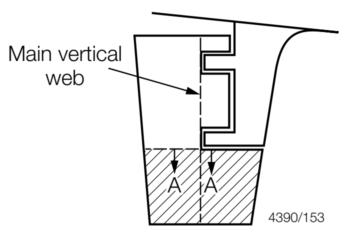


Fig. 3.2.3 Semi-spade (mariner) type rudder

Table 3.2.9 Double plated rudder construction

Item		Requirement
(1) Side plating		$t = \beta\, F_a\, (0{,}003 y_w + 2{,}03)(1{,}45 + 0{,}1 \sqrt{d_s}\,)$ mm
(2) Webs - vertical and horizontal		As (1) above
(3) Top and bottom plates		As (1) above using y_w = maximum rudder width, in mm, at top or bottom, but not less than 900 mm
(4) Nose plates		$t_N \geq 1{,}25t$ from (1) above
(5) Mainpiece – fabricated rectangular		Breadth and width $\geq d_s$ $t_M = F_a\, (8{,}5 + 0{,}56 \sqrt{d_s}\,)$ mm Minimum fore and aft extent of side plating = $0{,}2x_B$ Stress due to bending $\leq$ 78,0 N/mm^2
(6) Mainpiece – tubular		Inside diameter $\geq d_s$ t_M as for (5) above Side plating as for (1) above Bending stress as for (5) above
(7) Testing	Pressure	2,45 m head, and rudder should normally be tested while laid on its side
	Leak (air pressure)	0,02 N/mm^2 and arrangements made to ensure that no pressure in excess of 0,03 N/mm^2 can be applied
Symbols		
β = $A_a\,(1 - 0{,}25A_a)$ A_a = panel aspect ratio, but is not to be taken as greater than 2,0 F_a = 1,0 for mild steel, 0,95 for aluminium alloy and 0,9 for stainless steel. Other materials will be specially considered t = thickness, in mm y_w = vertical spacing, in mm, of the horizontal webs or arms, but is not to exceed 900 mm d_s = basic stock diameter, given by Table 3.2.7, in mm t_N = thickness, in mm, of nose plate t_M = thickness, in mm, of side plating and vertical webs forming mainpiece x_B = breadth of rudder, in metres, on centreline of stock		

2.14.4 Adequate hand or access holes are to be arranged in the rudder plating in way of pintles as required, and the rudder plating is to be reinforced locally in way of these openings. Continuity of the modulus of the rudder mainpiece is to be maintained in way of the openings.

2.14.5 Connection of rudder side plating to vertical and horizontal webs, where internal access for welding is not practicable, is to be by means of slot welds onto flat bars on the webs. The slots are to have a minimum length of 75 mm and in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded. The space between the slots is not to exceed 150 mm and welding is to be based on a weld factor of 0,44.

2.14.6 For testing of rudders, *see* Table 1.7.1 in Chapter 1.

2.14.7 Where the fabricated mainpiece of a spade rudder is connected to the horizontal coupling flange by welding, a full penetration weld is required.

2.15 Cast metal rudders

2.15.1 Where rudders are cast, the mechanical and chemical properties of the metal are to be submitted for approval. If the rudder stock is cast integral with the rudder blade, abrupt changes of section and sharp corners are to be avoided.

2.16 Lowest main bearing requirement

2.16.1 The design of the lowest bearing is to comply with the requirements of Table 3.2.10.

2.17 Bearings

2.17.1 Bearings are to be of approved materials and effectively secured to prevent rotational and axial movement.

2.17.2 Synthetic rudder stock bearing materials are to be of a type approved by LR.

2.17.3 Where it is proposed to use stainless steel bearings for rudder stocks, the chemical composition is to be submitted for approval.

Table 3.2.10 Lowest main bearing requirements

Item	Requirement	
Lowest main bearing	Depth Z_B, in mm $1,5d_s \geq Z_B \geq 1,0d_s$	Minimum thickness of wall, in mm lesser of $0,2d_s$ or 100
Bearing pressure (on the projected area of the lowest main bearing), where the projected area is to be taken as the length x diameter	Bearing material	Maximum pressure, in N/mm^2 (*see* Note 4)
	Metal	7,0
	Synthetic	5,5
Clearance in lowest main bearing on the diameter (note should be taken of the manufacturer's recommended clearances, particularly where bush material requires pre-soaking)	Bearing material	Minimum clearance, in mm (*see* Note 3)
	Metal (*see* Note 2)	$0,001d_s + 1,0$
	Synthetic	$0,002d_s + 1,0$ but not less than 1,5
Symbols		
d_s = stock diameter, given by Table 3.2.7, in mm		
NOTES 1. Where web stiffening is fitted on the bearing, a reduction in wall thickness will be considered. 2. For bearings which are pressure lubricated the clearance must be restricted to enable the pressure to be maintained. 3. Value of proposed minimum clearance is to be indicated on plans submitted for approval. 4. Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results.		

2.17.4 When stainless steel bearings are used, arrangements to ensure an adequate supply of sea-water to the bearing are to be provided.

2.17.5 When the rudder stock or liner is grade 316L austenitic stainless steel, it is recommended that gunmetal, lignum vitae or a synthetic bearing material be used in the bush. If a stainless steel is used in the bush, it is to be of a different grade and with an adequate hardness difference. The use of a ferritic/austenitic duplex structure stainless steel is recommended for the bush but 17 per cent to 30 per cent chromium stainless steels are also suitable.

2.18 Liners

2.18.1 Where liners are fitted to rudder stocks or pintles, they are to be shrunk on or otherwise efficiently secured.

2.18.2 Where it is proposed to use stainless steel liners, the chemical composition is to be submitted for approval.

2.18.3 When stainless steel liners are used, arrangements to ensure an adequate supply of sea-water to the liner are to be provided.

2.19 Pintles

2.19.1 Rudder pintles and their bearings are to comply with the requirements of Table 3.2.11.

2.19.2 Where the lower pintle is housed above the rudder gudgeon, *see* Fig. 3.2.4, and not below as shown in Fig. 3.2.5, C_{PL} is to be measured to the top of the gudgeon.

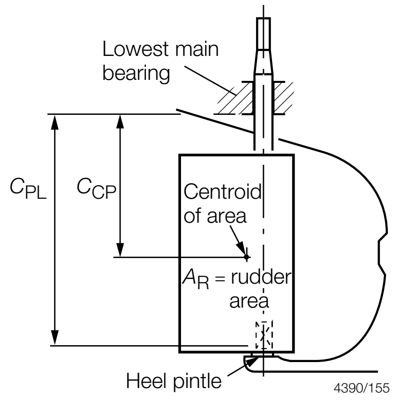


Fig. 3.2.4
Lower pintle housed above rudder gudgeon

2.19.3 Special attention is to be paid to the fit of the pintle taper into its socket. To facilitate removal of the pintles, it is recommended that the taper is to be not less than half the maximum value given in Table 3.2.11.

Table 3.2.11 Pintle requirements

Item	Requirement	
(1) Pintle diameter (measured outside liner if fitted)	$\delta_{PL} = \sqrt{\left(\dfrac{235}{\sigma_o}\right)^m}\ (31 + 4{,}17V\sqrt{A_{PL}}\,)$ mm For single pintle rudders and lower pintle of semi-spade rudders:: $A_{PL} = \dfrac{A_R\,C_{CP}}{C_{PL}}$ m^2 but for semi spade rudders need not be taken greater than A_R Upper pintle on semi-spade rudders; $A_{PL} = A_R\left(1 - \dfrac{C_{CP}}{C_{PL}}\right)$ m^2 or 0,35A_R m^2, whichever is the greater For rudders with two or more pintles (except semi-spade rudders): $A_{PL} = \dfrac{A_R}{N_{PL}}$ m^2	
(2) Maximum pintle taper	Method of assembly	Taper (on diameter)
	Manual assembly, key fitted (pintle ≤ 200mm diameter) Manual assembly, key fitted (pintle ≥ 400mm diameter)	1 in 6 1 in 9
	For keyed and other manually assembled pintles with diameters between 200 mm and 400 mm, the taper is to be obtained by interpolation.	
	Hydraulic assembly, dry fit Hydraulic assembly, oil injection	1 in 12 1 in 15
(3) Bearing length	$Z_{PB} \geq 1{,}2\delta_{PL}$ mm May be less for very large pintles if bearing pressure is not greater than that given in (4), but Z_{PB} must not be less than $1{,}0\delta_{PL}$ mm	
(4) Bearing pressure (on projected area)	Bearing material	Pressure
	Metal Synthetic	7,0 N/mm^2 5,5 N/mm^2
	Using force acting on bearing: $P_{PL} = \dfrac{A_{PL}\,(V+3)^2\,f_R}{10}$ kN A_{PL} as for item (1)	
(5) Gudgeon thickness in way of pintle (measured outside bush if fitted)	$b_G \geq 0{,}5\delta_{PL}$ but need not normally exceed 125mm	
(6) Pintle clearance (note should be taken of the manufacturer's recommended clearances particularly where bush material requires pre-soaking). Value of proposed minimum clearance is to be indicated on plans submitted for approval.	Bearing material	Minimum clearance, mm
	Metal Synthetic	$0{,}001\delta_{PL} + 1{,}0$ $0{,}002\delta_{PL} + 1{,}0$ but not less than 1,5

Symbols

δ_{PL} = pintle diameter, in mm
V = as defined in Table 3.2.7 but not less than 10 knots
A_{PL} = rudder area supported by the pintle, in m^2
C_{CP}, C_{PL} = dimensions in metres, as indicated in Figs. 3.2.4 and 3.2.5
A_R = rudder area, in m^2
σ_o = as defined in Table 3.2.7
N_{PL} = number of pintles on the rudder
Z_{PB} = pintle bearing length, in mm
P_{PL} = force acting on bearing, in kN
b_G = thickness of gudgeon material in way of pintle, in mm
f_R = rudder profile coefficient, *see* Table 3.2.1
m = as defined in Table 3.2.7

NOTE
Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results.

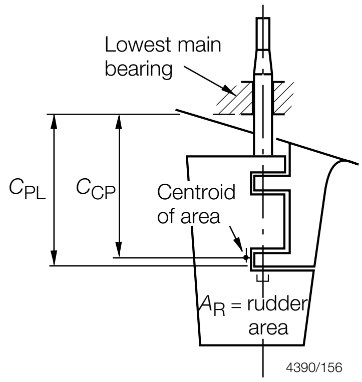


Fig. 3.2.5
Lower pintle housed below rudder gudgeon

2.19.4 The distance between the lowest rudder stock bearing and the upper pintle is to be as short as possible.

2.19.5 Where liners are fitted to pintles, they are to be shrunk on or otherwise efficiently secured. If liners are to be shrunk on, the shrinkage allowance is to be indicated on the plans. Where liners are formed by stainless steel weld deposit, the pintles are to be of weldable quality steel and details of the procedure are to be submitted.

2.19.6 The bottom pintle on semi-spade (Mariner) type rudders are:

(a) If inserted into their sockets from below, to be keyed to the rudder or sternframe as appropriate or to be hydraulically assembled, with the nut adequately locked, or
(b) If inserted into their sockets from above, to be provided with an appropriate locking device, the nut being adequately secured.

2.19.7 Where an ***IWS** (In-water Survey) notation is to be assigned, *see* 2.37.

2.20 Bolted couplings

2.20.1 Rudder coupling design is to be in accordance with Table 3.2.12.

2.20.2 Where coupling bolts are required they are to be fitted bolts. Suitable arrangements are to be made to lock the nuts.

2.20.3 For rudders with horizontal coupling arrangements, where the upper flange is welded to the rudder stock, a full penetration weld is required and its integrity is to be confirmed by non-destructive examination. Such rudder stocks are to be subjected to a furnace post-weld heat treatment (PWHT) after completion of all welding operations. For carbon or carbon manganese steels, the PWHT temperature is not to be less than 600°C.

2.20.4 The connecting bolts for coupling the rudder to the rudder stock are to be positioned with sufficient clearance to allow the fitting and removal of the bolts and nuts without contacting the palm radius, *R*, *see* Fig. 3.2.6(a). The surface forming the palm radius is to be free of hard and sharp corners and is to be machined smooth to the Surveyor's satisfaction. The surface in way of bolts and nuts is to be machined smooth to the Surveyor's satisfaction.

2.20.5 For spade rudders fitted with a fabricated rectangular mainpiece, the mainpiece is to be designed with its forward and aft transverse sections at equal distances forward and aft of the rudder stock transverse axis, *see* Fig. 3.2.6(b).

2.21 Conical couplings

2.21.1 Where a rudder stock is connected to a rudder by a keyless fitting, the rudder is to be a good fit on the rudder stock cone. During the fit-up, and before the push-up load is applied, an area of contact of at least 90 per cent of the theoretical area of contact is to be achieved, and this is to be evenly distributed. The relationship of the rudder to stock at which this occurs is to be marked, and the push-up then measured from that point. The upper edge of the upper mainpiece bore is to have a slight radius. After the final fitting of the stock to the rudder, positive means are to be used for locking the securing nut to the stock.

2.21.2 Where a keyed tapered fitting of a rudder stock to a rudder is proposed, a securing nut of adequate proportions is to be provided. After the final fitting of the stock to the rudder, positive means are to be used for locking this nut.

2.22 Rudder carrier arrangements

2.22.1 The weight of the rudder is to be supported at the heel pintle or by a carrier attached to the rudder head. The hull structure supporting the carrier bearing is to be adequately strengthened. The plating under all rudder-head bearings or rudder carriers is to be increased in thickness.

2.23 Anti-jump collars

2.23.1 Suitable arrangements are to be provided to prevent the rudder from lifting.

2.23.2 Jumping collars are not to be welded to the rudder stock.

2.24 Drain plugs

2.24.1 Where rudders are of plated construction, drain plugs are to be provided to ensure that all compartments can be adequately drained. These plugs are to be locked and details of their scantlings, arrangements and position clearly indicated on the rudder plan.

Table 3.2.12 Rudder couplings to stock *(see continuation)*

Arrangement	Parameter	Requirement	
		Horizontal coupling	Vertical coupling
(1) Bolted couplings (*see* Notes)	n	≥ 6	≥ 8
	δ_b	$\dfrac{0{,}65 d_s}{\sqrt{n}}$	$\dfrac{0{,}81 d_s}{\sqrt{n}}$
	m	$0{,}00071 n\, d_s\, \delta_b^2$	$0{,}00043 d_s^3$
	t_f	$\geq \delta_b$ (*see* Note 1)	δ_b
	α_{max} (*see* Note 2)	$(53{,}82 - 35{,}29 k_1)\dfrac{d_s^3}{P_L\, h 10^6} - \left(1{,}8 - 6{,}3\dfrac{R}{d_s}\right)\dfrac{t_f - t_{fa}}{t_{fa}}$	—
	$\alpha_{as\ built}$ (*see* Note 2)	$\leq \alpha_{max}$	—
	w_f	$0{,}67\delta_b$	$0{,}67\delta_b$
(2) Conical couplings	θ_t	$\leq \dfrac{1}{K_1}$	
	l_t	$\geq 1{,}5 d_s$	
	$\bar{p}$	$\dfrac{P_R\, \theta_t\, \bar{\delta}_{ST} + 4M_T \sqrt{K_2\left(\left(\dfrac{P_R\, \bar{\delta}_{ST}}{2M_T}\right)^2 + 1\right) - \left(\dfrac{\theta_t}{2}\right)^2}}{5{,}66\bar{\delta}_{ST}^2\, l_t \left(K_2 - \left(\dfrac{\theta_t}{2}\right)^2\right)}$	
	w	$\dfrac{9{,}6 \times 10^{-6}\, \bar{p}\, \bar{\delta}_{ST}}{\theta_t (1 - \bar{f}^2)}$	
	P_u	Approximately equal to $2{,}83\, \bar{p}\, l_t\, \bar{\delta}_{ST} \left(K_3 + \dfrac{\theta_t}{2}\right)$	
	P_o	Approximately equal to $2{,}83\, \bar{p}\, l_t\, \bar{\delta}_{ST} \left(K_3 - \dfrac{\theta_t}{2}\right)$	
	σ_o	$\geq \dfrac{12{,}35 \times 10^4\, w\, \theta_t \sqrt{3 + f^4}}{\delta_{ST}}$	

2.25 Corrosion protection

2.25.1 All metalwork, is to be suitably protected against corrosion. This may be by coating or, where applicable, by a system of cathodic protection.

2.25.2 Metalwork is to be suitably cleaned before the application of any coating. Where appropriate, blast cleaning or other equally effective means are to be employed for this purpose.

2.26 Dissimilar materials

2.26.1 Where materials vary for individual components, they are to be compatible to avoid galvanic corrosion. Scantling calculations for the components are to be based on d_s for the relevant material, *see* Table 3.2.7.

2.27 Internal coatings

2.27.1 Internal surfaces of the rudder are to be efficiently coated or the rudder is to be filled with foam plastics. Where it is intended to fill the rudder with plastic foam, details of the foam are to be submitted.

2.28 Pressure testing

2.28.1 For testing of rudders, *see* Table 1.7.1 in Chapter 1.

2.29 Tiller arms, quadrants

2.29.1 Tillers and quadrants are to comply with the requirements of Table 1.4.1 in Pt 14, Ch 1.

Table 3.2.12 Rudder couplings to stock (*conclusion*)

Symbols

n = number of bolts in coupling

δ_b = diameter of coupling bolts, in mm

d_s, d_{su} = rudder stock diameter as defined in Table 3.2.7

m = first moment of area of bolts about centre of coupling, in cm^3

k_1 = the greater of k_s and k_f

k_s = $\left(\frac{235}{\sigma_o}\right)^m$ where σ_o is the specified minimum yield stress at the rudder stock and m is as defined in Table 3.2.7

k_f = $\left(\frac{235}{\sigma_o}\right)^m$ where σ_o is the specified minimum yield stress at the upper coupling flange and m is as defined in Table 3.2.7

h = vertical distance between the centre of pressure and the centre point of the palm radius, R, in metres, *see* Fig. 3.2.6(a)

R = palm radius between rudder stock and connected flange, not smaller than $\frac{d_s}{10}$, in mm

t_f = minimum thickness of coupling flange, in mm

t_{fa} = as built flange thickness, in mm

α_{max} = maximum allowable stress concentration factor

$\alpha_{as\ built}$ = stress concentration factor for as built scantlings

$= \dfrac{0,73}{\sqrt{\left(\frac{R}{d_s}\right)}}$

w_f = width of flange material outside the bolt holes, in mm

θ_t = taper of conical coupling, on the diameter, e.g.:

$\theta_t = \frac{1}{15} = 0,067$

l_t = length of taper, in mm

$\bar{p}$ = required mean grip stress, in N/mm^2

w = corresponding push-up of rudder stock, in mm

P_u, P_o = corresponding push-up, pull-off loads respectively, in N

σ_o = minimum yield stress of stock and gudgeon material, in N/mm^2. σ_o is not to be taken greater than 70 per cent of the ultimate tensile strength

P_R = effective weight of rudder, in N

$\bar{\delta}_{ST}$ = mean diameter of coupling taper, in mm

δ_{ST} = diameter of coupling taper at any position, in mm

$\bar{\delta}_{GH}$ = mean external diameter of gudgeon housing, in mm

δ_{GH} = external diameter of gudgeon housing at any position, in mm

$\bar{f} = \dfrac{\bar{\delta}_{ST}}{\bar{\delta}_{GH}}$

$f = \dfrac{\delta_{ST}}{\delta_{GH}}$

M_T = maximum torque applied to stock, and is to be taken as the greater of M_F, M_A or M_W.

M_F = $P_L X_{PF} \times 10^6$ Nmm in the ahead condition

M_A = $P_L X_{PA} \times 10^6$ Nmm in the astern condition

M_W = the torque generated by the steering gear at the maximum working pressure supplied by the manufacturer, in Nmm. M_W is not to exceed the greater of $3,0M_F$ or $3,0M_A$

P_L = lateral force on rudder acting at centre of pressure in ahead and astern conditions, as defined in Table 3.2.7, in kN

X_{PF}, X_{PA} = the horizontal distances, in metres, *see* Table 3.2.6

K_1, K_2, K_3 = constants depending on the type of assembly adopted as follows:

		K_1	K_2	K_3
Oil injection method	with key	15	0,0064	0,025
	without key	15	0,0036	0,025
Dry fit method	with key	12	0,0128	0,170
	without key	12	0,0072	0,170

NOTES

1. For spade rudders with horizontal coupling, t_f is not to be less than $0,25d_s$.
2. This requirement is applicable only for spade rudders with horizontal couplings, *see* Fig. 3.2.6.
3. Where materials vary for individual components, scantling calculations for such components are to be based on d_s for the relevant material.

2.29.2 The steering gear is to be mounted on a seat and adequately secured.

2.30 Connecting bars

2.30.1 Connecting bars are to comply with the requirements of Pt 14, Ch 1,4.3.3.

2.31 Keys and keyways

2.31.1 Where the tiller or quadrant is bolted, a key having an effective cross-sectional area in shear of not less than $0,25d_{SU}^2$ mm^2 is to be fitted. The thickness of the key is to be not less than $d_{SU}/6$ mm. Alternatively, the rudder stock may be machined to a square section in lieu of fitting a key. d_{SU} is as defined in Table 3.2.7.

2.31.2 Keyways are to extend over the full depth of the tiller boss.

2.31.3 Keyways in the rudder stock are to have rounded ends and the corners at the base of the keyway are to be radiused.

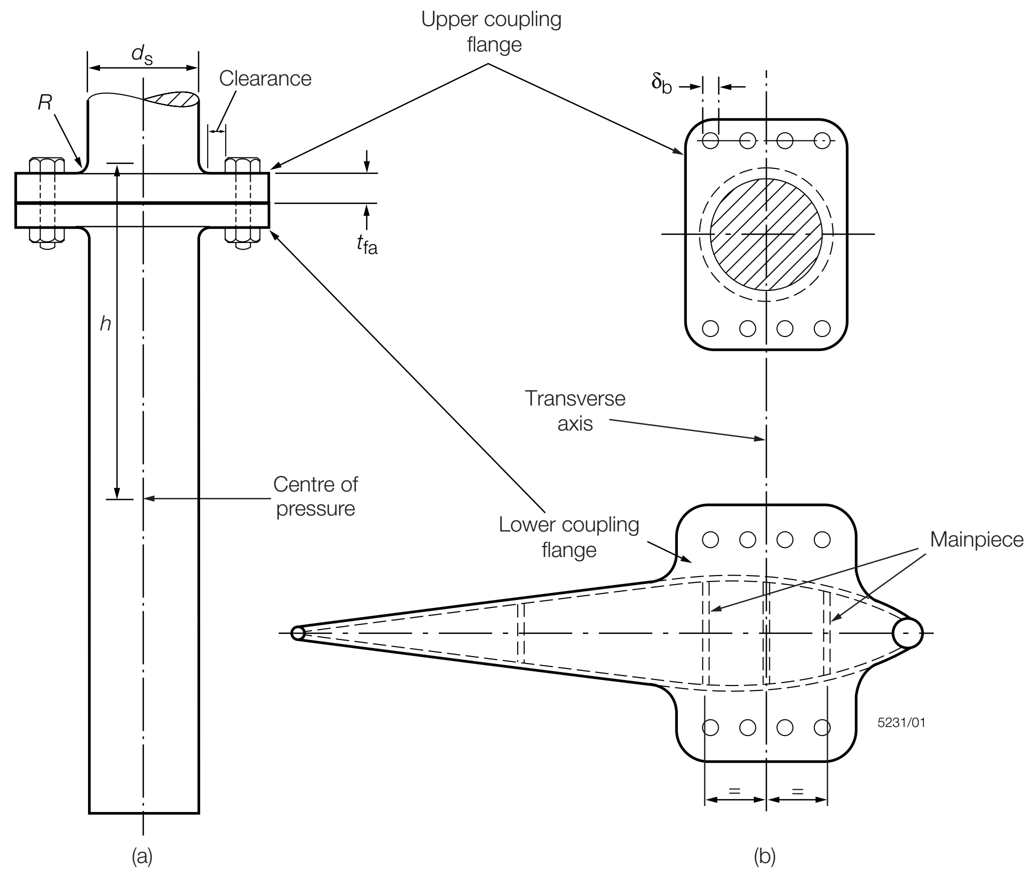


Fig. 3.2.6 Rudder stock connection

2.32 Stopping arrangements

2.32.1 Suitable rudder stops are to be provided to limit the rudder angle to the desired level port and starboard. These stops are to be of substantial construction and efficiently connected to the supporting structure.

2.33 Novel designs

2.33.1 Where rudders are of a novel design they may be specially considered on the basis of the Rules. Alternatively the Builder's/designer's calculations are to be submitted for consideration.

2.34 FRP double plated rudders

2.34.1 Fibre reinforced plastic rudders are to incorporate a metallic framework, consisting of a mainpiece fitted with arms, within the blade, or an equivalent arrangement. Where rudder blades are moulded in halves they are to be effectively joined together by means of external overbonding of the joint or suitable mechanical fastening or equivalent. Both halves of the rudder blade moulding are to be effectively connected to the metallic framework and mainpiece by either mechanical means or suitable bonded connection.

2.34.2 Rudders are to be filled with a suitable material upon completion of the join up, details of the filler material are to be submitted.

2.34.3 The diameter of the top of the rudder mainpiece must not be less than that of the rudder stock. For spade rudders this diameter may be gradually reduced for the lower third to not less than 75 per cent of the rudder stock diameter.

2.34.4 The rudder arms are to be efficiently attached to the mainpiece.

2.34.5 The laminate weight of moulded fibre reinforced plastics double plate rudders is to be determined by direct calculation, subject to a minimum laminate thickness of 5 mm.

2.35 Rudder tube arrangements

2.35.1 The rudder tube construction may be of aluminium alloy, steel, bronze or fibre reinforced plastic.

2.35.2 The scantlings of rudder tubes will be individually considered.

2.35.3 For steel and aluminium hulls, the bottom shell in way of the rudder tubes is to be additionally reinforced by means of an insert plate to increase the bottom shell thickness by 50 per cent.

2.35.4 For F.R.P. hulls, the bottom shell laminate in way of the rudder tubes is to be locally increased by 50 per cent. The increased thickness in way of the rudder tube need not exceed the rule keel thickness requirement.

2.35.5 For F.R.P. sandwich hulls the shell in way of the rudder tube connection is to be either:

(a) Reduced from the sandwich hull construction to single skin laminate for a distance of a least three times the rudder tube diameter about the rudder stock axis. The single skin region is to be additionally reinforced by a minimum of 50 per cent of the sum of the inner and outer sandwich laminate subject to this being at least equivalent to a 50 per cent increase in thickness of the Rule minimum bottom shell laminate for a single skin F.R.P. craft of the equivalent Rule length, L_R. The reinforced laminate need not be greater than the Rule keel laminate thickness.

(b) Reduced from the sandwich hull construction to a single skin laminate for a distance of three times the rudder tube diameter about the rudder stock axis. After bonding in the rudder tube to the single skin laminate the foam core and inner skin are then reinstated.

(c) Proposals to replace the sandwich core with a core having higher core shear strength and compressive strength than that of the adjacent structure prior to bonding the tube to the inner and outer skins will be the subject of special consideration.

2.35.6 The rudder tube may be connected to the shell by bonding, bolting or welding as applicable depending upon the construction material of the shell.

2.35.7 When bonding in rudder tubes the bonding angle is to be not less than the Rule minimum bottom shell weight. F.R.P. tubes are to be thoroughly abraded and degreased prior to installation and laminating. Bonded in metallic tubes are to be knurled in way of the bonding material and thoroughly degreased prior to installation.

2.35.8 Where rudder tubes are to be retained by bolting they are to be provided with a substantial flange securely attached to the hull structure. Where bolts are used, the nuts are to be suitably locked.

2.35.9 Where rudder tubes are to be welded to hull insert plates full penetration welding is required.

2.35.10 Rudder tubes are to be supported by suitable brackets and deep floors to avoid hard spots on the shell and to ensure continuity of the main hull structure.

2.35.11 Rudder bearings are to be secured against rotation within the rudder tubes by suitable pinch bolting or keys. Details are to be submitted for approval.

2.36 Watertight gland

2.36.1 In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided. Rudder trunk boundaries where exposed to the sea are to have a corrosion protection coating applied in accordance with the manufacturer's instructions.

2.36.2 Where the top of the rudder tube is significantly higher than the deepest load waterline a lesser arrangement of watertightness, such as 'O' rings may be accepted.

2.36.3 The watertight gland body may be formed by the top of the fabricated or cast rudder tube. The gland packing being retained against the top bearing or a check in the wall of the rudder tube and is compressed by a gland packet which may be of the flange type, screwed cap or other suitable arrangement.

2.36.4 Alternative arrangements utilizing lip seals or 'O' rings, either in isolation or in combination with one or other of the alternative seal arrangements, will be the subject of special consideration.

2.37 In-water Survey requirements

2.37.1 Where an ***IWS** (In-water Survey) notation is to be assigned, *see* Pt 1, Ch 2,3.8, means are to be provided for ascertaining the rudder pintle and bush clearances and for verifying the security of the pintles in their sockets with the craft afloat.

■ *Section 3* Sternframes and appendages

3.1 General

3.1.1 Stern frames, rudder horns and boss end brackets may be constructed of cast or forged steel, cast or forged aluminium alloy, fabricated from aluminium or steel plate or moulded from fibre reinforced plastic dependent upon the material of construction of the craft. Where shaft brackets are fitted these may be either fabricated, cast or forged from steel or aluminium alloy as applicable to the material of construction of the main hull.

3.1.2 In castings, sudden changes of section or possible constrictions to the flow of metal during casting are to be avoided. All fillets are to have adequate radii, which, in general, are to be not less than 50 to 75 mm, depending on the size of the casting.

3.1.3 Castings and forgings are to comply with the requirements of Chapters 4 and 5 of the Rules for Materials.

3.1.4 Sternframes, rudder horns, shaft brackets, etc., are to be effectively integrated into the craft structure, and their design is to be such as to facilitate this.

3.2 Sternframes

3.2.1 The scantlings of sternframes are to be determined from Table 3.3.1. In the case of very large craft, the scantlings and arrangements may be required to be verified by direct calculations.

3.2.2 Fabricated and cast propeller posts and rudder posts of twin screw craft are to be strengthened at intervals by webs. In way of the upper part of the sternframe arch, these webs are to line up with the floors.

3.2.3 Rudder posts and propeller posts are to be connected to floors of increased thickness. *See* Ch 3,5.10 of Parts 6 and 7 for steel and aluminium alloy construction respectively.

3.2.4 The requirements for sternframes of composite craft are to be in accordance with Pt 8, Ch 3,5.9.

3.3 Rudder horns

3.3.1 The requirements for the scantlings and arrangements of rudder horns are given in Ch 3,5.9 of Parts 6 and 7 for steel and aluminium alloy construction and Pt 8, Ch 3,5.8 for composite construction respectively.

3.4 Shaft bossing

3.4.1 Where the propeller shafting is enclosed in bossings extending back to the bearings supporting the propellers, the aft end of the bossings and the bearings are to be supported by substantially constructed boss end castings or fabrications. These are to be designed to transmit the loading from the shafting efficiently into the craft's internal structure.

3.4.2 For shaft bossings attached to shaft brackets, the length of the boss is to be adequate to accommodate the aftermost bearing and to allow for proper connection of the shaft brackets.

3.4.3 Cast steel supports are to be suitably radiused where they enter the main hull to line up with the boss plating radius. Where the hull sections are narrow, the two arms are generally to be connected to each other within the craft. The arms are to be strengthened at intervals by webs.

3.4.4 Fabricated supports are to be carefully designed to avoid or reduce the effect of hard spots. Continuity of the arms into the craft is to be maintained, and they are to be attached to substantial floor plates or other structure. The connection of the arms to the bearing boss is to be by full penetration welding.

3.4.5 The scantlings of supports will be specially considered. In the case of certain high powered craft, direct calculations may be required.

3.4.6 The boss plating is generally to be radiused into the shell plating and supported at the aft end by diaphragms at every frame. These diaphragms are to be suitably stiffened and connected to floors or a suitable arrangement of main and deep web frames. At the forward end, the main frames may be shaped to fit the bossing, but deep webs are generally to be fitted not more than four frame spaces apart.

3.5 Shaft brackets

3.5.1 The scantlings of the arms of shaft brackets, based on a breadth to thickness ratio of about five, are to be determined from 3.6.1 and 3.7.2.

3.5.2 Where the propeller shafting is exposed to the sea for some distance clear of the main hull, it is generally to be supported adjacent to the propeller by independent brackets having two arms. In very small craft the use of single arm brackets will be considered.

3.5.3 Fabricated brackets are to be designed to avoid or reduce the effect of hard spots and ensure a satisfactory connection to the hull structure. The connection of the arms to the bearing boss is to be by full penetration welding.

3.5.4 Where bracket arms are carried through the shell plating, they are to be attached to floors or girders of increased thickness. The shell plating is to be increased in thickness and connected to the arms by full penetration welding.

3.5.5 In the case of certain high powered craft direct calculations may be required.

3.5.6 For shaft brackets having hollow section arms, the cross-sectional areas at the root and the boss should be not less than that required for a solid arm which satisfies the Rule section modulus having the proportions stated in 3.5.1.

3.5.7 The length of the shaft bracket boss, l_b, is to be sufficient to support the length of the required bearing. In general l_b is not to be less than $4d_t$, where d_t is the Rule diameter of the screwshaft, in mm, *see* Pt 11, Ch 2,4.4. Proposals for a reduction in the required shaft bracket boss length will be considered in conjunction with details of the bearing material, allowable bearing operating pressure and installation arrangements, *see* Pt 11, Ch 2,4.16.2. However in no case is l_b to be less than the greater of:

(a) $2d_t$; or
(b) that recommended by the bearing manufacturer; or
(c) as required by 3.4.2.

Table 3.3.1 Sternframes (*see continuation*)

Item	Parameter	Requirement		
(1) Propeller posts		Cast steel (*see* Fig. 3.3.1(a))	Forged Steel (*see* Fig. 3.3.1(b))	Fabricated mild steel (*see* Fig. 3.3.1(c))
	l	$165\sqrt{T}$ mm	—	$200\sqrt{T}$ mm
	r	$20\sqrt{T}$ mm	—	$18\sqrt{T}$ mm
	t_W	$8\sqrt{T}$ mm (need not exceed 38 mm) (*see* Notes 1 and 2)	—	$6\sqrt{T}$ mm (need not exceed 30 mm) (*see* Notes 1 and 2)
	t_1	$12\sqrt{T}$ mm (min 19 mm)	—	$12\sqrt{T}$ mm
	t_2	$16\sqrt{T}$ mm (min 25 mm)	—	—
	W	$115\sqrt{T}$ mm	$40\sqrt{T}$ mm	$140\sqrt{T}$ mm
	A	—	$(10 + 0{,}5L_R)T$ cm^2 where $L_R \leq 60$ m $40T$ cm^2 where $L_R > 60$m	—
(2) Propeller boss (*see* Note 3 and Fig. 3.3.2)	t_b	$(0{,}1\delta_{TS} + 56)$ mm, but need not exceed $0{,}3\delta_{TS}$		
(3) Rudder posts or axles		Single screw with integral solepiece, *see* Fig. 3.3.5 (a)	Single screw with bolted rudder axle, with hull, *see* Fig. 3.3.3	Twin screw, integral *see* Fig. 3.3.4
	n	—	6 (*see* Note 4)	—
	r	—	—	$20\sqrt{T}$ mm
	r_b	—	δ_A mm	—
	t_F	—	δ_b mm	—
	t_1	—	—	$12\sqrt{T}$ mm
	t_2	—	—	$15\sqrt{T}$ mm
	t_3	—	—	$18\sqrt{T}$ mm
	w	—	—	$120\sqrt{T}$ mm
	z_{PB1}, z_{PB2}	—	$1{,}2\delta_{PL2}$ mm	—
	Z_T	$0{,}147A_R\,b(V + 3)^2$ cm^3	—	—
	δ_A	—	$(25T + 76)$ mm but need not exceed $0{,}9\delta_{PL2}$ mm	—
	δ_b	—	$6{,}25T + 19$ mm or $0{,}225\delta_{PL2}$ mm whichever is the greater	—
	$\delta_{PL1}, \delta_{PL2}$ bearing pressure and pintle clearance	—	As for rudder pintles (*see* Table 3.2.11)	—
(4) Solepieces (*see* Notes 5,6 and 7)		With integral rudder post, *see* Fig. 3.3.5(a)	With bolted axle, *see* Fig. 3.3.5(b)	Open type (no rudder post), *see* Fig. 3.3.5(c)
(a) Cast steel	Z_T	$0{,}50W$ cm^3	$0{,}95W$ cm^3	$1{,}00W$ cm^3
	Z_V	$0{,}35W$ cm^3	$0{,}40W$ cm^3	$0{,}50W$ cm^3
(b) Fabricated mild steel	Z_T	$0{,}42W$ cm^3	$0{,}81W$ cm^3	$0{,}85W$ cm^3

Table 3.3.1 Sternframes *(conclusion)*

Symbols	
L_R, T as defined in Ch1,6.2 a,b,c = distances, in metres, as shown in Fig. 3.3.5 n = number of bolts in palm coupling r_b = mean distance of bolt centres from centre of palm, in mm t_b = finished thickness of boss, in mm x = distance, in metres, from centre of rudder stock to section under consideration A = cross-sectional area of forged steel propeller post, in cm^2 A_R = total rudder area, in m^2 L_1 = L_R, but is to be taken not less than 90 m	V = maximum service speed, in knots, with the craft in the loaded condition $W = \dfrac{400 A_R\, C\, (V + 3)^2\, (3x + a)}{b\, (L_1 + 640)}$ Z_T = section modulus against transverse bending, in cm^3 Z_V = section modulus against vertical bending, in cm^3 δ_b = diameter of coupling bolts, in mm δ_{TS} = diameter of tail shaft, in mm
NOTES 1. Where scantlings and proportions of the propeller post differ from those shown in Item 1, the section modulus about the longitudinal axis of the proposed section normal to the post is to be equivalent to that with Rule scantlings. t_1 is to be not less than 8 $\sqrt{T}$ (minimum of 19 mm for cast steel sternframes) 2. On sternframes without solepieces, the modulus of the post below the propeller boss, about the longitudinal axis may be gradually reduced to not less than 85% of that required by Note 1, subject to the same thickness limitations. 3. In fabricated sternframes the connection of the propeller post to the boss is to be by full penetration welds. 4. If more than six bolts are fitted, the arrangements are to provide equivalent strength.	5. In fabricated solepieces, transverse webs are to be fitted spaced not more than 760 mm apart. Where the breadth of the solepiece exceeds 900 mm, a centreline vertical web is also to be fitted. 6. Solepieces supporting fixed or movable nozzles will be specially considered (*see* 4.2). 7. For dredging and reclamation craft in restricted service Groups G1, G2 or G3, the scantlings of an ‘open’ type solepiece are to be such that: (a) Z_T = 0,625W cm^3. (b) The cross-sectional area is not less than 18 cm^2. (c) The depth is not less than two-thirds of the width at any point.

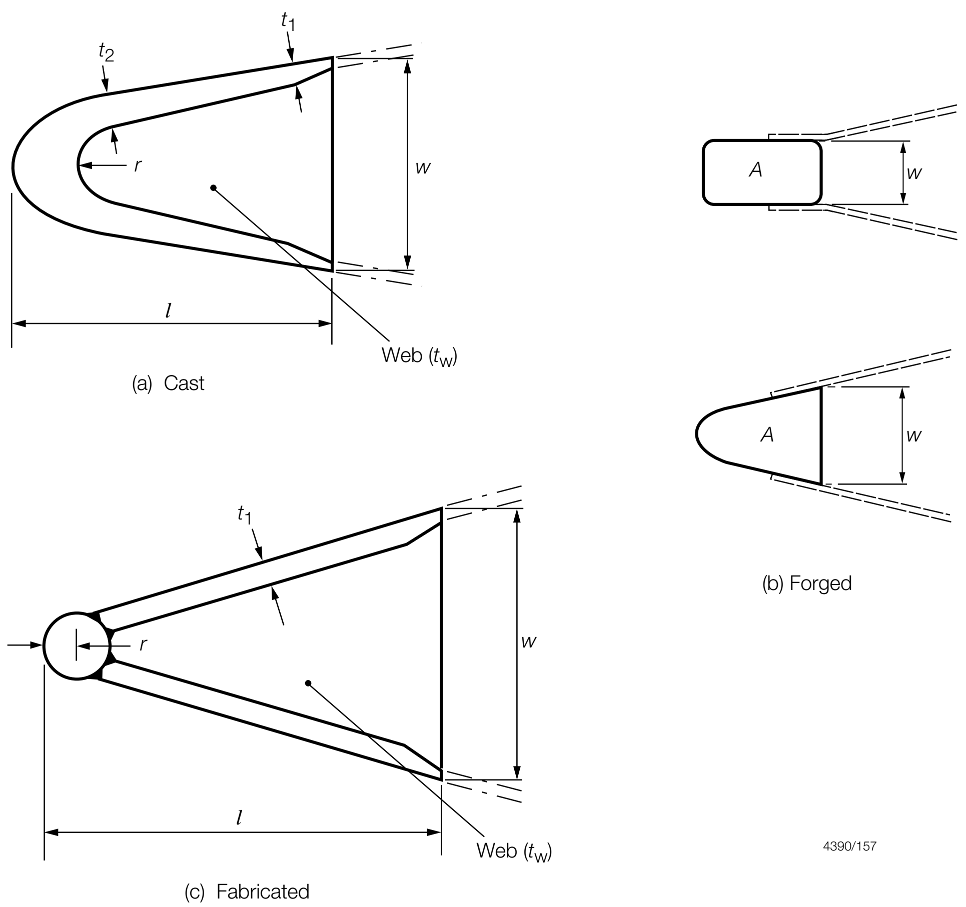


Fig. 3.3.1 Propeller posts

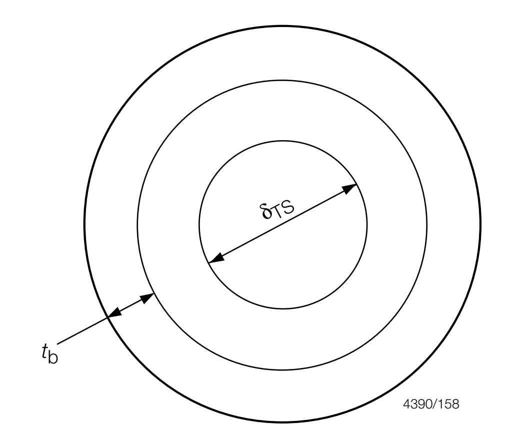


Fig. 3.3.2 Propeller boss

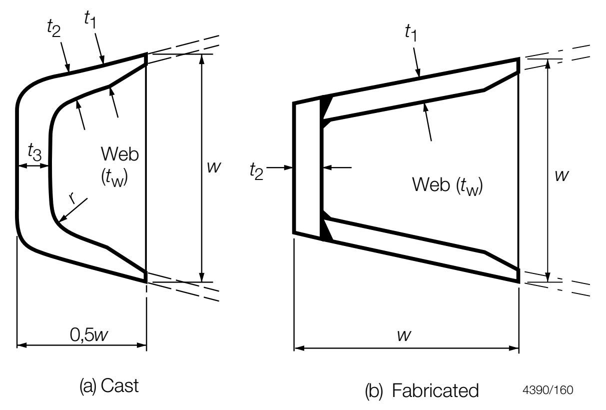


Fig. 3.3.4 Rudder post for twin screw craft

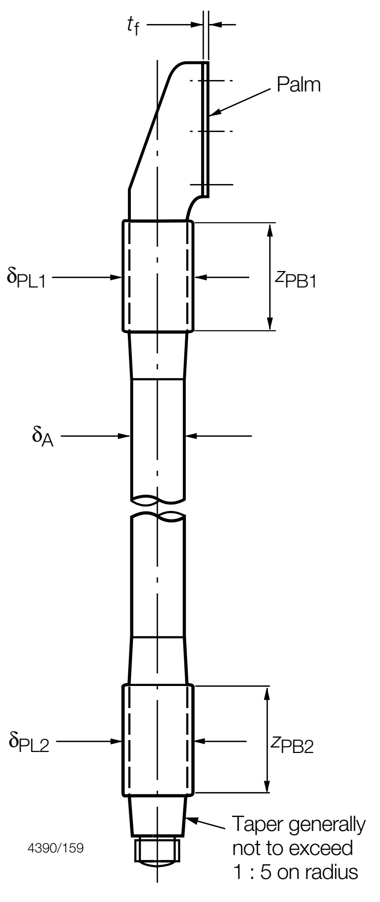


Fig. 3.3.3 Rudder axle

3.5.8 Where the shaft and the shaft bracket boss are of the same material, the thickness of the shaft bracket boss is not to be less than $d_t/4$. Where the shaft and the shaft bracket boss are of dissimilar materials, the thickness of the boss, t_b, is to be not less than:

$$t_b = 0{,}75 d_t \left(\sqrt[3]{f_1} - 0{,}667\right) \text{ mm}$$

NOTE:
In no case is t_b to be taken as less than 12 mm.

where
- d_t = Rule diameter of the screwshaft, in the appropriate screwshaft material, in mm, *see* Pt 11, Ch 2,4
- f_1 = σ_S/σ_B but not less than 0,825
- σ_S = ultimate tensile strength of the shaft material, in N/mm^2
- σ_B = ultimate tensile strength of the boss material, in N/mm^2.

3.5.9 The design of the shaft brackets with regard to disturbance of the hydrodynamic flow into the propeller and rudders is outwith the scope of classification.

3.6 Single arm shaft brackets ('P' – brackets)

3.6.1 Single arm shaft brackets are to have a section modulus, Z_{xx}, at the palm of not less than that determined from the formula:

$$Z_{xx} = \frac{a_s\, d_t^2\, f}{45000} \text{ cm}^3$$

where
- a_s = the length of the arm to be measured from the centre of the section at the palm to the centreline of the shaft boss, in mm, *see* Fig. 3.3.6
- d_t = the Rule diameter for an unprotected screwshaft, in mm, as given in Pt 11, Ch 2,4, using A = 1,0
- f = $400/\sigma_u$
- σ_u = ultimate tensile strength of arm material, in N/mm^2

The cross-sectional area of the bracket at the boss is to be not less than 60 per cent of the area of the bracket at the palm.

3.6.2 For single arm shaft brackets a vibration analysis may be required if deemed necessary by LR.

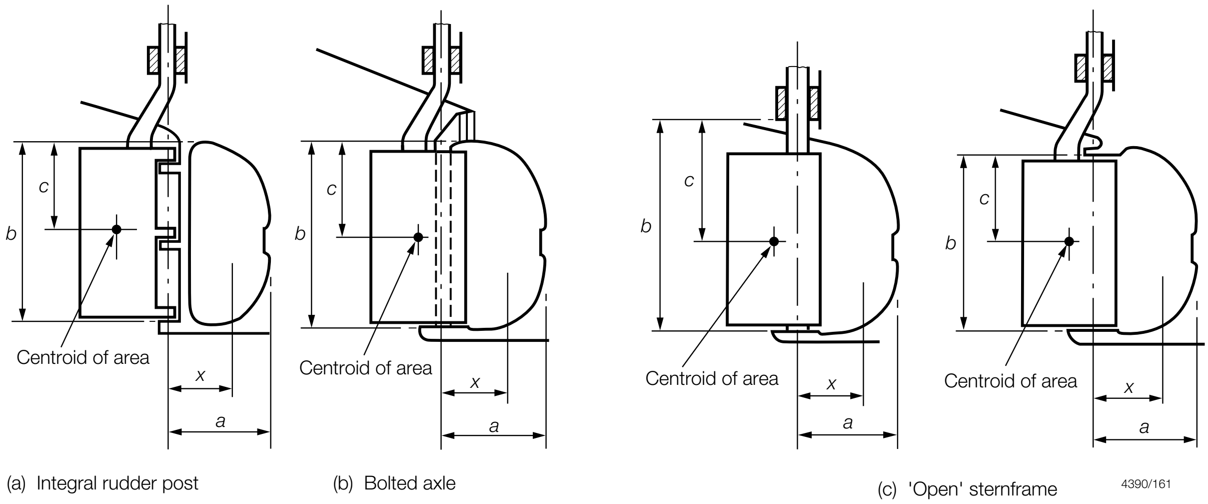


Fig. 3.3.5 Solepiece

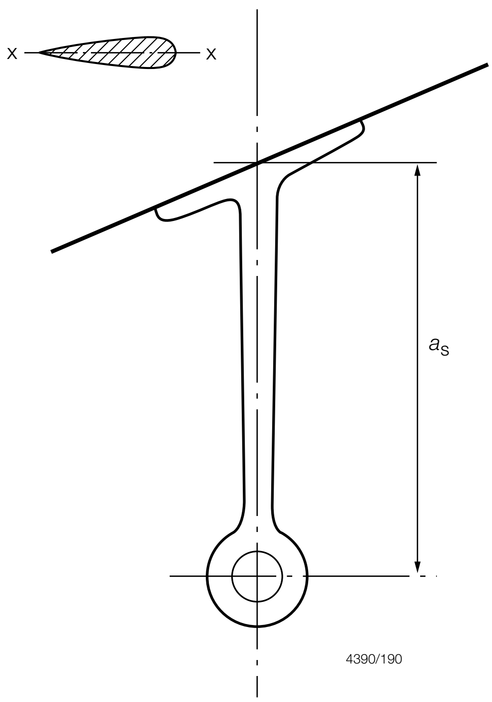


Fig. 3.3.6 Single arm shaft bracket

3.7 Double arm shaft brackets ('A' – brackets)

3.7.1 The angle between the arms for double arm shaft brackets is to be generally not less than 50°. Proposals for the angle between the arms to be less than 50° will be specially considered with supporting calculations to be submitted by the designers.

3.7.2 The arms of double arm shaft brackets are to have a section modulus, Z_{xx}, of not less than that determined from the formula:

$Z_{xx} = 0{,}45\, n^3$ cm^3

where

n = the minimum thickness, in cm, of a hydrofoil section obtained from:

$$n = d_t \sqrt{\left(\frac{f}{2000}\right)\left(1 + \sqrt{\left(1 + \left(\frac{0{,}0112}{f}\right)\left(\frac{a_d}{d_t}\right)^2\right)}\right)} \text{ cm}$$

a_d = the length of the longer strut, in mm, *see* Fig. 3.3.7

d_t and f are as given in 3.6.1.

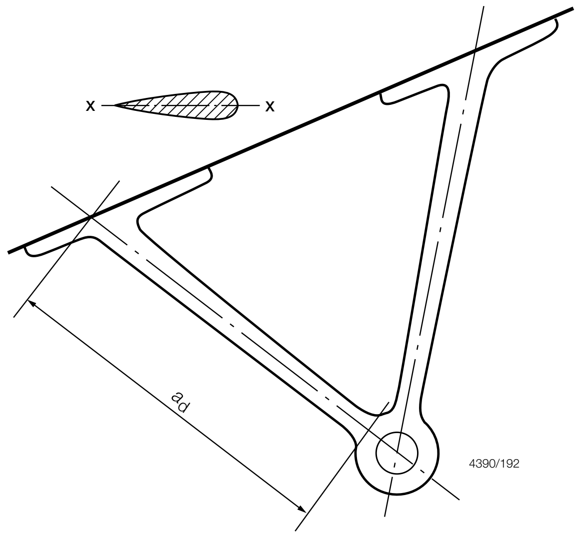


Fig. 3.3.7 Double arm shaft bracket

3.8 Intermediate shaft brackets

3.8.1 The length and thickness of the shaft bracket boss are to be as required by 3.5.7 or 3.5.8 as appropriate. The scantlings of the arms will be specially considered on the basis of the Rules.

3.9 Attachment of shaft brackets by welding

3.9.1 Fabricated supports are to be carefully designed to avoid or reduce the effect of hard spots. Continuity of the arms into the craft is to be maintained, and they are to be attached to substantial floor plates or other structure. The connection of the arms to the bearing boss is to be by full penetration welding.

3.10 Attachment of shaft brackets by bolting

3.10.1 The bottom shell thickness in way of the double arm propeller bracket palms is to be increased by 50 per cent. The bottom shell thickness in way of single arm propeller brackets palms is to be doubled in thickness. The insert plates, or reinforced shell laminate in FRP craft, are to be additionally supported by substantial floor plates or other structure.

3.10.2 Where shaft brackets are attached by bolts, they are to be provided with substantial palms securely attached to the hull structure which is to be adequately stiffened in way. Where bolts are used, the nuts are to be suitably locked.

3.10.3 The bracket palms may be bolted directly onto the shell using a suitable bedding compound. The palms may be bolted onto suitable shims or chocking compound, of an approved type, to facilitate alignment.

3.10.4 Where brackets are bolted onto resin chocks, plans indicating the following information are to be submitted for approval:

(a) The thrust and torque loads, where applicable, that will be applied to the chocked item.
(b) The torque load to be applied to the bracket mounting bolts.
(c) The material of the bracket mounting bolts.
(d) The number, thread size, shank diameter and length of the mounting bolts.

3.10.5 The minimum thickness of a resin chock is to be 12 mm.

3.10.6 The bracket palms are to have well radiused corners, and the faying surface to be dressed smooth. The palm thickness in way of the bolts is to be not less than the propeller bracket boss thickness from 3.5.7 or 3.5.8 as appropriate.

3.10.7 The diameter of the propeller bracket mounting bolts is to be not less than:

$$d_b = \sqrt{\frac{Z_{xx}}{8,75\,\pi\, n\, h \times 10^{-5}}} \text{ mm}$$

and not less than the shell plate thickness in way of the palm or 12 mm, whichever is greater

where

Z_{xx} = the section modulus of the bracket arm determined from 3.6.1 or 3.7.2, in cm^3, as appropriate
n = the number of bolts in each row
h = the distance between rows of bolts, in mm
d_b = the bolt diameter in the same material as the propeller bracket, in mm.

3.10.8 Where the shaft bracket and the shaft bracket mounting bolts are of dissimilar materials (which are galvanically compatible), the diameter of the propeller bracket mounting bolts, as determined from 3.10.7, is to be modified in proportion to the square root of the yield strengths of the particular materials. The corrected bolt diameter of the dissimilar material is to be not less than the propeller bracket boss thickness.

3.10.9 The propeller bracket palms are to have fitted bolts, and suitable arrangements provided to lock the nuts.

3.10.10 A washer plate is to be provided, generally of equal dimensions to the bracket palm with thickness t_b/6 mm, subject to a minimum of 3 mm.

3.11 Attachment of shaft brackets by bonding

3.11.1 Proposals to connect shaft brackets to FRP hulls by bonding will be the subject of special consideration. Details of the following are to be submitted:

(a) Preparation of the hull penetration and internal bonding surface.
(b) Details of transverse through pinning of the shaft bracket strut.
(c) Details of over bonding of strut and pin arrangement and subsequent integration of strut into primary hull structure.

3.12 Alignment of shaft brackets

3.12.1 Particular care is to be paid to the alignment of shaft brackets to minimise vibration and cyclic loadings being transmitted from the propulsion shafting and propellers into the hull structure.

3.12.2 Alignment of bolted shaft brackets may be by means of suitable metallic shims or chocking resin of an approved type. *See* 3.10.2 and 3.10.3.

3.12.3 The alignment of shaft brackets connected by welding or bonding may be facilitated by boring of the bracket boss after attachment of the shaft bracket and stern tube.

3.13 Sterntubes

3.13.1 The sterntube construction may be of aluminium alloy, steel, bronze or fibre reinforced plastic.

3.13.2 The sterntube scantlings are to be individually considered.

3.13.3 For steel and aluminium hulls, the bottom shell, in way of the sterntube, is to be additionally reinforced by means of an insert plate to increase the bottom shell thickness by 50 per cent.

3.13.4 For FRP hulls, the bottom shell laminate, in way of the sterntube, is to be locally increased by 50 per cent by gradual tapering of the laminate. The increased thickness in way of the sterntube need not exceed the Rule keel thickness requirement.

3.13.5 For FRP sandwich hulls, the shell in way of the stern tube connection is to be either:

(a) Reduced from sandwich hull construction to single skin laminate by removal of the core and by combining the inner and outer skins. The single skin region is then to be additionally reinforced by a minimum of 50 per cent of the sum of the inner and outer sandwich laminate. The increased thickness in way of the sterntube need not be greater than the Rule keel thickness requirement.

(b) Reduced from the sandwich hull construction to a single skin laminate by removal of the core and combining the inner and outer skins. After bonding in the stern tube to the single skin laminate the foam core and the inner skin is to be reinstated.

(c) Proposals to replace the sandwich core with a core having higher core shear strength and compressive strength than that of the adjacent structure prior to bonding the tube to the inner and outer skins will be the subject of special consideration.

3.13.6 The sterntube may be connected to the shell by bonding, bolting or welding as applicable depending upon the construction material of the shell.

3.13.7 When bonding in sterntubes the bonding angle laminate weight is to be not less than the Rule minimum bottom weight. FRP tubes are to be thoroughly abraded and degreased prior to installation and laminating. Bonded in metallic tubes are to be knurled in way of the bonding material and thoroughly degreased prior to installation. During the bonding operation particular care is to be given to maintaining the sterntube alignment.

3.13.8 Where sterntubes are to be retained by bolting, they are to be provided with a substantial flange securely attached to the hull structure. Where bolts are used, the nuts are to be suitably locked.

3.13.9 Where sterntubes are to be welded to hull insert plates full penetration welding is required.

3.13.10 Where sterntubes are to be installed using a resin system, of an approved type, the requirements of Pt 11, Ch 2,4.16 are to be complied with.

3.13.11 The region where the shafting enters the craft, and the bearing in way, is to be adequately supported by floors or deep webs.

3.13.12 The shaft bearings are to be secured against rotation within the sterntube.

3.13.13 A suitable gland arrangement is to be provided at the inboard end of sterntubes in accordance with Pt 11, Ch 2,4.15.

3.14 Solepieces

3.14.1 The requirements for solepieces are as indicated in Table 3.3.1.

3.15 Propeller hull clearances

3.15.1 Recommended minimum clearances between the propeller and the sternframe, rudder or hull are given in Table 3.3.2. These are the minimum distances considered desirable in order to expect reasonable levels of propeller excited vibration. Attention is drawn to the importance of the local hull form characteristics, shaft power, water flow characteristics into the propeller disc and cavitation when considering the recommended clearances.

Table 3.3.2 Recommended propeller hull clearances

Number of Blades	Hull clearances for single screw, in metres, *see* Fig. 3.3.8(a)				Hull clearances for twin screw, in metres, *see* Fig. 3.3.8(b)	
	a	b	c	d	e	f
3	$1{,}20K\delta$	$1{,}80K\delta$	$0{,}12\delta$	$0{,}03\delta$	$1{,}20K\delta$	$1{,}20K\delta$
4	$1{,}00K\delta$	$1{,}50K\delta$	$0{,}12\delta$	$0{,}03\delta$	$1{,}00K\delta$	$1{,}20K\delta$
5	$0{,}85K\delta$	$1{,}275K\delta$	$0{,}12\delta$	$0{,}03\delta$	$0{,}85K\delta$	$0{,}85K\delta$
6	$0{,}75K\delta$	$1{,}125K\delta$	$0{,}12\delta$	$0{,}03\delta$	$0{,}75K\delta$	$0{,}75K\delta$
Minimum value	$0{,}10\delta$	$0{,}15\delta$	t_R	—	3 and 4 blades, $0{,}20\delta$ 5 and 6 blades, $0{,}16\delta$	$0{,}15\delta$

Symbols

L_R and C_b as defined in Ch 1,6.1

$$K = \left(0{,}1 + \frac{L_R}{3050}\right)\left(\frac{3{,}48 C_b P_s}{L_R^2} + 0{,}3\right)$$

t_R = thickness of rudder, in metres measured at $0{,}7R_p$ above the shaft centreline

P_s = designed power on one shaft, in kW

R_p = propeller radius, in metres

δ = propeller diameter, in metres

NOTE
The above recommended minimum clearances also apply to semi-spade type rudders.

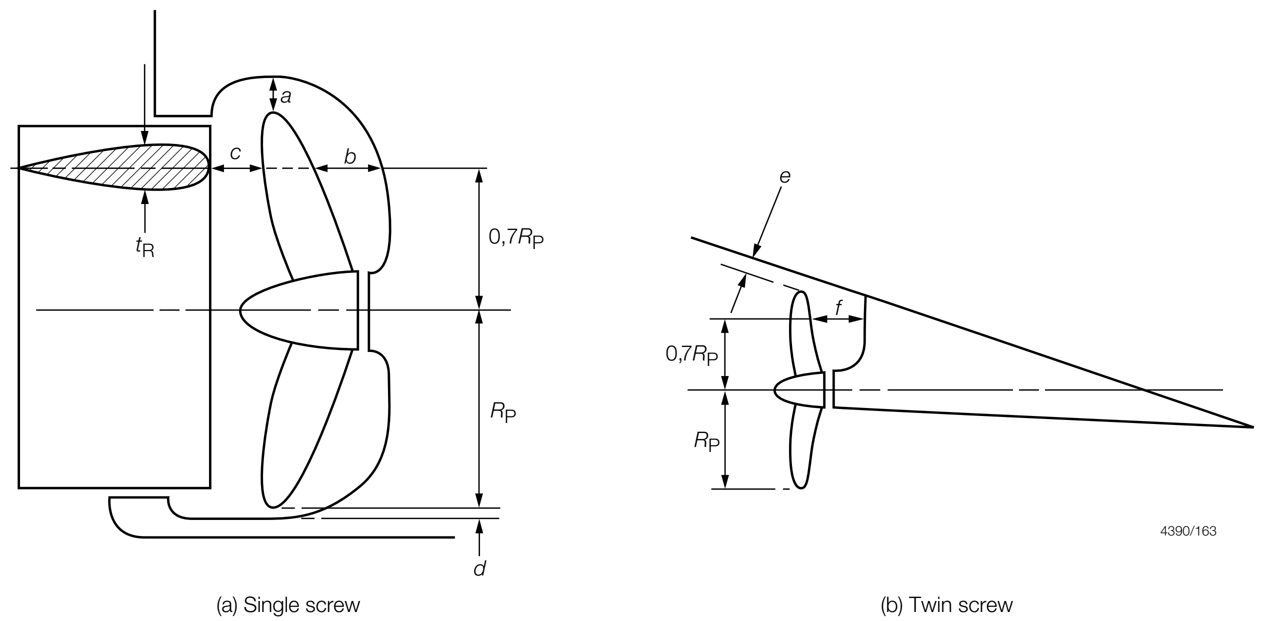


Fig. 3.3.8 Propeller clearance

■ *Section 4*
Fixed and steering nozzles, bow and stern thrust units

4.1 General

4.1.1 The requirements for scantlings for fixed and steering nozzles are given, for guidance only, in 4.2 to 4.4 and Table 3.4.1.

4.1.2 The requirements, in general, apply to nozzles with a numeral not greater than 200, *see* Table 3.4.1. Nozzles exceeding this value will be specially considered.

4.2 Nozzle structure

4.2.1 For basic scantlings of the structure, *see* Table 3.4.1, in association with Fig. 3.4.1.

4.2.2 The shroud plating in way of the propeller tips is to be carried well forward and aft of this position, due allowance being made on steering nozzles for the rotation of the nozzle in relation to the propeller.

4.2.3 Fore and aft webs are to be fitted between the inner and outer skins of the nozzle. Both sides of the headbox and pintle support structure are to be connected to fore and aft webs of increased thickness. For thicknesses, *see* Table 3.4.1.

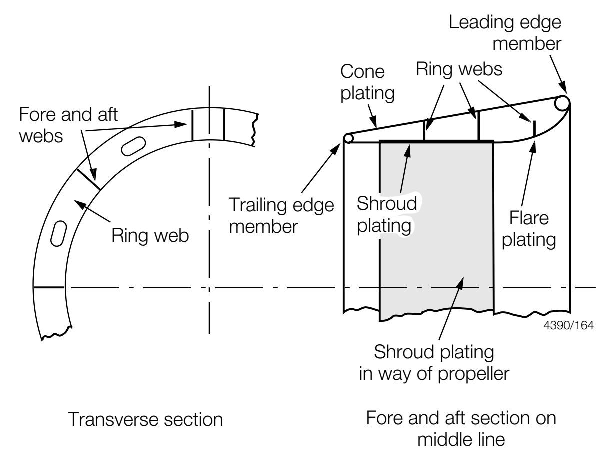


Fig. 3.4.1 Fixed and steering nozzles

Table 3.4.1 Nozzle construction requirements

Item	Requirement
(1) Nozzle Numeral	$N_N = 0{,}01P\delta_P$
(2) Shroud plating in way of propeller blade tips	For $N_N \leq 63$ $t_s = (11 + 0{,}1N_N)$ mm For $N_N > 63$ $t_s = (14 + 0{,}052N_N)$ mm
(3) Shroud plating clear of blade tips, flare and cone plating, wall thickness of leading and trailing edge members	$t_p = (t_s - 7)$ mm but not less than 8mm
(4) Webs and ring webs	As item (3) except in way of headbox and pintle support where $t_W = (t_s + 4)$ mm
(5) Nozzle stock	Combined stresses in stock at lower bearing $\leq 92{,}7$ N/mm^2 Torsional stress in upper stock $\leq 62{,}0$ N/mm^2
(6) Solepiece and strut	Bending stresses not to exceed $70{,}0$ N/mm^2
Symbols	
N_N = a numeral dependent on the nozzle requirements P_s = power transmitted to the propellers, in kW δ_P = diameter of the propeller, in metres t_S = thickness of shroud plating in way of propeller tips, in mm t_p = thickness of plating, in mm t_W = thickness of webs and ring webs in way of headbox and pintle support, in mm	
NOTE Thicknesses given are for mild steel. Reductions in thickness will be considered for certain stainless steels.	

4.2.4 The transverse strength of the nozzle is to be maintained by the fitting of ring webs. Two ring webs are to be fitted in nozzles not exceeding 2,5 m diameter. Nozzles between 2,5 and 3,0 m in diameter are generally to have two full ring webs and a half-depth web supporting the flare plating. The number of ring webs is to be increased as necessary on nozzles exceeding 3,0 m in diameter. Where ring webs are increased in thickness in way of the headbox and pintle support structure in accordance with Table 3.4.1, the increased thickness is to be maintained to the adjacent fore and aft web.

4.2.5 Local stiffening is to be fitted in way of the top and bottom supports which are to be integrated with the webs and ring webs. Continuity of bending strength is to be maintained in these regions.

4.2.6 Fin plating thickness is to be not less than the cone plating, and the fin is to be adequately reinforced. Solid fins are to be not less than 25 mm thick.

4.2.7 Care is to be taken in the manufacture of the nozzle to ensure its internal preservation and watertightness. The preservation and testing are to be as required for rudders, *see* 2.25 and 2.27, and Table 1.7.2 in Chapter 1.

4.3 Nozzle stock and solepiece

4.3.1 Stresses, derived using the maximum side load on the nozzle and fin acting at the assumed centre of pressure, are not to exceed the values given in Table 3.4.1, in both the ahead and astern conditions.

4.4 Ancillary items

4.4.1 The diameter and first moment of area about the stock axis of coupling bolts and the diameter of pintles, are to be derived from 2.20 and 2.19 respectively.

4.4.2 Suitable arrangements are to be provided to prevent the steering nozzle from lifting.

4.5 Steering gear and allied systems

4.5.1 For the requirements of steering gear, *see* Pt 12, Ch 1.

4.6 Thruster unit wall thickness

4.6.1 The wall thickness of the unit is, in general, to be in accordance with the manufacturer's practice, but is to be not less than:

(a) For steel hulls, the thickness of the adjacent shell plating plus 10 per cent or 2 mm whichever is the greater, subject to a minimum of 7 mm.

(b) For aluminium hulls, the thickness of the adjacent shell plating plus 10 per cent or 1 mm whichever is the greater, subject to a minimum of 8 mm.

(c) For FRP hulls, generally the thickness of the adjacent shell laminate plus 25 per cent subject to a minimum of 8 mm. Full details of the proposed laminate and resin system are to be submitted for approval.

4.7 Thruster unit installation details

4.7.1 The method of attachment of the tube is dependent upon the tube and the craft's construction materials which may be steel, aluminium alloy or FRP.

4.7.2 The tunnel tube is to be fitted either between a pair of deep floors or bulkheads extending to above the design waterline or in a separate watertight compartment.

4.7.3 The shell plating thickness is to be locally increased by 50 per cent in way of tunnel thruster connections.

4.7.4 For welded tube connections the welding is to be by full penetration welding.

4.7.5 For FRP tubes attached by bonding the total bonding reinforcement weight is to be at least that of the hull bottom laminate with the tube bonded internally and externally to the shell laminate. Prior to bonding *in situ* the areas to be bonded are to be thoroughly abraded and degreased and all cut FRP laminate edges resin sealed.

4.7.6 The tunnel tube is to be framed to the same standard as the surrounding shell plating.

4.7.7 The unit is to be adequately supported and stiffened.

4.8 Novel features

4.8.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

■ *Section 5* Stabiliser arrangements

5.1 General

5.1.1 The scantlings, arrangements and effectiveness of the stabilisers are outwith the scope of classification; however their foundations, supporting structure and watertight integrity are to be examined.

5.2 Fin stabilisers

5.2.1 Detailed plans are to be submitted clearly indicating the position, supporting structure and design loads for all fins.

5.2.2 The design, construction, operational performance and control systems of the fin stabiliser unit are outside the scope of classification.

5.2.3 Fin stabilisers are to be contained within a watertight enclosure. The purpose of the watertight enclosure is to ensure that any impact to the stabiliser will not affect the survivability or safe operation of the craft. In addition to the requirements of 5.2.4, when determining the location and extent of the watertight enclosure the following should be considered:

(a) Stabiliser blade construction material
(b) Designed failure mode of stabiliser shaft
(c) Damage stability requirements of craft
(d) Survivability of craft after impact to the stabiliser
(e) Function of space containing stabiliser.

5.2.4 For non-retractable type stabilisers, the watertight divisions forming the forward and aft boundaries of the watertight enclosure are to be arranged not less than one third of the root chord length, C, from the fore and aft extents of the stabiliser, *see* Fig 3.5.1. Main watertight subdivision bulkheads may be considered as watertight divisions where appropriate.

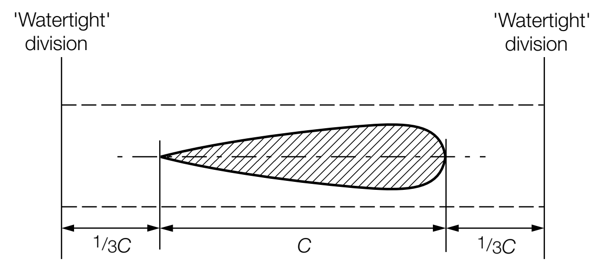


Fig. 3.5.1 Stabiliser positioning

5.2.5 For craft constructed of mild steel the watertight enclosure into which the stabilisers retract is to have a perimeter plating of the same thickness as the surrounding Rule shell plating plus 2 mm, and is to be stiffened to the same standard as the shell. For craft constructed from aluminium alloys the corrections in Ch 3,1.2.2 apply.

5.2.6 For craft constructed from composite materials the laminate thickness of the watertight enclosure into which the stabilisers retract is to be specially considered. Generally the thickness should not be less than that of the bottom shell.

5.2.7 Insert plates are to be fitted or laminate thickness increased in way of stabilisers. The thickness of the insert plate or increased laminate is to be at least 50 per cent greater than the bottom shell thickness in way, and is to extend over an area formed by 1,25 times the stabiliser root chord length and covering all operational angles. In addition, for retractable stabilisers the insert is to extend beyond the shell opening for a distance of not less than 25 per cent the length of the root chord.

5.2.8 Fin stabiliser systems are, in general, not to extend beyond the extreme moulded beam of the hull or below the horizontal line of keel. However, for retractable fins, alternative arrangements may be specially considered. Where the stabiliser fin extends beyond the extreme moulded beam of the hull in the active mode, the side shell is to be permanently marked indicating the forward and aft extent of the stabiliser when deployed. It is recommended that an appropriate symbol be placed on the hull side between the marks.

5.2.9 The stabiliser machinery and surrounding structure is to be adequately supported and stiffened. Where bending stresses are induced in the structure under fatigue conditions the maximum stress is not to exceed 39,0 N/mm^2 in mild steel. Where other materials are used for the supporting structure the limiting stress values will be specially considered on the basis of the Rules.

5.2.10 The scantlings of internal watertight bulkheads and stiffening for fixed installations are to be as specified by the designer/Builder and/or fin unit manufacturer but in no case are to be less than the scantlings for double bottoms as defined in Pt 6, Ch 3,6 for steel structures and Pt 7, Ch 3,6 for aluminium structures. Suitable access is to be provided to allow for maintenance and inspection purposes.

5.2.11 The scantlings and sealing arrangements for the pedestal and bearings will be specially considered, subject to the designer/Builder submitting the following:

(a) Detailed structural calculations for the proposed foundation and adjacent supporting structure.
(b) A detailed finite element model, if carried out, *see* Pt 3, Ch 1,2.
(c) Calculations demonstrating that the effect of damage to the stabiliser arrangement arising from high speed impact, grounding, fouling, etc will not compromise the structural and watertight integrity of the craft.
(d) Maximum torque, bending moments and bearing loads expected for the proposed design.
(e) The stabiliser fin stock material, together with its ultimate tensile and shear strength values (N/mm^2).

5.2.12 Fin bearing materials and seals are to be of an approved type.

5.2.13 Where retractable stabilisers are fitted, position indicators are to be provided on the bridge and adjacent to the stabiliser installation.

5.3 Stabiliser tanks

5.3.1 The general structure of the tank is to comply with the Rule requirements for deep tanks. Sloshing forces in the tank structure are to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

5.4 Ride control systems

5.4.1 The scantlings, arrangements and effectiveness of ride control systems are currently outwith the scope of classification; however their foundations, supporting structure and watertight integrity together with the associated reaction forces on the hull structure are to be examined. Details of the loadings and supporting calculations are to be submitted with the relevant construction plans for consideration.

5.5 Motion damping arrangements and devices

5.5.1 Motion damping devices are generally outwith the scope of the Rules. Where motion damping devices are fitted the designers/Builders are to submit details of the anticipated loadings and supporting calculations for appraisal of the adjacent hull structure.

5.6 Novel features

5.6.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

■ *Section 6* Particular requirements for multi-hull craft

6.1 General

6.1.1 The requirements for control systems of multi-hull craft are generally in accordance with the requirements of Sections 1 to 5 for mono-hulls.

6.2 Rudders

6.2.1 The scantlings for rudders are to be generally in accordance with Ch 3,2. Where the proposed rudder is of a novel design or the speed of the craft exceeds 45 knots the scantlings of the rudder and rudder stock are to be determined from direct calculation methods incorporating model test results and structural analysis, as considered necessary by LR.

6.3 Sternframes and appendages

6.3.1 Sternframes and appendages are to be considered on the basis of the Rules. Reference is also to be made to Chapter 5, (Special Features) of Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively.

6.4 Fixed and steering nozzles, bow and stern thrust units

6.4.1 In general, the requirements are to be in accordance with Ch 3,4.

6.5 Stabiliser arrangements

6.5.1 In general, the requirements for multi-hulls are to be in accordance with the requirements of Ch 3,5 and Ch 5,2.4 of Parts 6, 7 and 8, dependent upon the material of construction.

■ *Section 1* General

1.1 Application

1.1.1 The contents of this Chapter are applicable to mono-hull and multi-hull craft constructed in steel, aluminium alloy or composite materials.

1.1.2 Where the requirements of Pt 1, Ch 2,1.1.11 and 1.1.14 require the craft to be subdivided for damage stability aspects these will be considered in addition to the requirements of this Part.

1.1.3 Attention is, however, to be given to any other additional statutory requirements of the National Authority in which the craft is registered.

1.2 Downflooding

1.2.1 Yachts and craft to which the *International Convention on Load Lines*, 1966 is applicable, *see* Pt 1, Ch 2,1.1.11, are to comply with the requirements of this sub-Section.

1.2.2 Doors, hatches, ventilators, windows, portlights, etc. provided with closing appliances which can be secured weathertight, and small openings through which progressive flooding cannot take place are not considered as down flooding points.

1.2.3 Air pipes are to be fitted with automatic closing appliances unless it can be shown that, with the craft at its summer load waterline, the openings will not be immersed at an angle of heel of 40°, or the angle of downflooding if this is less than 40°.

1.3 Definitions and symbols

1.3.1 The **down flooding angle** is the least angle of heel at which openings in the hull, superstructure or deckhouses, which cannot be closed weathertight, immerse and allow flooding to occur.

1.3.2 L_L is the loadline length as defined in Ch 1,6.2.3.

1.3.3 Position 1 and Position 2 are as defined in Ch 1,6.10.

1.4 Bolted connections

1.4.1 Bolted connections are generally to be in accordance with Table 4.1.1. Further requirements are contained throughout this Chapter.

Table 4.1.1 Bolt pitch requirements for structural connections

Location	Pitch
Manhole covers to fuel tanks	$6d_b$
Manhole covers to water tanks	$8d_b$
Covers over void tanks/cofferdams	$10d_b$
Unstiffened portable plates in decks	$5d_b$
Bolted watertight door frames	$8d_b$
Window frames to superstructure	$20d_b$
NOTE d_b is the diameter of the bolt	

■ *Section 2* Bulkhead openings

2.1 General

2.1.1 In addition to the requirements of this Section, where compliance with Pt 4, Ch 2,9 and Chapter X of SOLAS 1974, as amended *(High Speed Craft Code)*, is required, the number and construction of the watertight doors in bulkheads will be considered in accordance with these requirements. Each watertight door is to be subjected to a pressure test, *see* Table 1.7.1 in Chapter 1. The test may be carried out either before or after the door is fitted. Regulations regarding openings in watertight bulkheads relevant to passenger or cargo craft, as appropriate, contained in the *International Convention for the Safety of Life at Sea, 1974* and applicable amendments, and Pt 4, Ch 2,9 are also to be complied with.

2.2 Openings in bulkheads below the freeboard deck

2.2.1 Certain openings below the freeboard deck are permitted, but these must be kept to a minimum and provided with means of closing to watertight standards. All such openings are to be to the satisfaction of the Surveyor.

2.3 Watertight doors

2.3.1 Watertight doors are to be efficiently constructed and fitted, and are to be capable of being operated when the craft is listed up to 15° either way. They are to be operated under working conditions and hose tested in place. *See* Ch 1,7.3.

2.3.2 Where the doors are fitted in watertight bulkheads they are to be of equivalent strength to the unpierced bulkhead and capable of being closed watertight. Watertight doors are to be of a type, approved and pressure tested, *see* Table 1.7.1 in Chapter 1, from both sides for the maximum head of water indicated by any required damage stability calculations or up to the bulkhead deck whichever is the greater.

2.3.3 Indicators are to be provided on the bridge showing whether the doors are open or closed.

2.3.4 Doors are to be capable of being operated from both sides of the bulkhead. Power operated sliding doors are to be capable of being opened and closed locally by both power and efficient hand operated mechanisms.

2.3.5 Doors not required to be used at sea may be of the hinged or sliding type. A notice is to be fixed on the closing appliance saying it should be kept closed at all times while the craft is at sea.

2.3.6 Watertight doors which are intended to be used while at sea are to be of the sliding type capable of being remotely closed from the bridge. An audible alarm is to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular care is to be paid to minimising the effect of control system failure.

2.3.7 As an alternative to the sliding doors required by 2.3.6, special consideration will be given to the fitting of hinged watertight doors where it can be shown that they are as effective as the sliding type. A suitable log-book system is to be operated to ensure that such doors remain closed except when in use for access.

2.3.8 Subject to the requirements of 2.3.6 and 2.3.7, hinged watertight doors of approved pattern may be fitted in 'tween decks in approved positions. The hinges of these doors are to be fitted with a pin or bush of a suitable copper alloy in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), or of an equivalent material acceptable to Lloyd's Register (hereinafter referred to as 'LR').

2.3.9 No accesses are to be fitted in collision bulkheads. In particular designs where it would be impracticable to arrange access to the fore peak other than through the collision bulkhead, access may be permitted subject to special consideration. Where accesses are provided, the openings are to be as small as practicable and positioned as far above the design waterline as possible. The closing appliances are to be watertight, open into the fore peak compartment and consideration will be given to operation from one side only.

2.4 Pipe and cable ducts, ventilation trunks and other penetrations

2.4.1 Where subdivision and damage stability requirements apply and where penetration of watertight divisions by pipes, ducts, trunks or other penetrations is necessary, arrangements are to be made to maintain the watertight integrity.

2.4.2 Ventilators from deep tanks and tunnels passing through 'tween decks are to have scantlings suitable for withstanding pressures to which they may be subjected, and are to be made watertight.

■ *Section 3* Double bottom openings

3.1 General

3.1.1 Provision is to be made for the free passage of air and water from all parts of the tanks to the air pipes and suctions, account being taken of the pumping rates required.

3.1.2 Adequate access is also to be provided to all parts of the double bottom for future maintenance, surveys and repairs. The edges of all openings are to be smooth.

3.2 Requirements

3.2.1 A plan showing the location of manholes and access openings within the double bottom is to be submitted. Attention is to be given to any relevant Statutory Requirements of the National Authority of the country in which the craft is to be registered.

3.2.2 The number and positioning of manholes are to be such that access under service conditions is neither difficult nor dangerous. Attention is to be given to any relevant international regulations regarding the minimum size of access openings.

3.2.3 Manholes and their covers are to be of an approved design or in accordance with a recognised National or International Standard.

3.2.4 The size of opening is not, in general, to exceed 50 per cent of the double bottom depth, unless edge reinforcement is provided. In way of outboard ends of floors and fore and aft girders at transverse bulkheads, the number and size of holes are to be kept to a minimum, and the openings are to be circular or elliptical. Edge stiffening may be required in these positions.

3.2.5 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or double plate bulkheads within one-third of their length from either end, nor in floors or double bottom girders close to their span ends, below the heels of pillars, nor in way of mast steps, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

3.2.6 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

3.2.7 Air and drain holes, notches and scallops are to be in accordance with Ch 2,4 of Parts 6 and 7 for steel and aluminium alloy construction respectively.

3.3 Alternative arrangements

3.3.1 The Rules are formed on the basis that access to double bottoms will be by means of manholes with bolted covers. However, alternative arrangements will be specially considered.

■ *Section 4*
Side and stern doors and other shell openings

4.1 General

4.1.1 These requirements cover cargo and service doors in the craft side (abaft the collision bulkhead) and stern area, below the freeboard deck and in enclosed superstructures.

4.1.2 For the requirements of bow doors, *see* Ch 5,4 of Parts 6 and 7 for steel and aluminium alloy construction respectively.

4.1.3 Side and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure. *See also* Ch 1,6.8.2 and 6.9.2.

4.1.4 In general, and for passenger craft in particular, the lower edge of door openings are not to be below a line drawn parallel to the freeboard deck at side, which is at its lowest point at least 230 mm above the upper edge of the uppermost Load Line.

4.1.5 When the lower edge is below the uppermost Load Line, the arrangement will be specially considered. Special consideration is to be given to preventing the spread of leakage water over the deck. The reference to the uppermost Load Line is to be taken as the tropical fresh water line.

4.1.6 Doors are generally to be arranged to open outwards, however inward opening doors will be considered provided strongbacks are fitted when the doors are situated in the first two 'tween decks above the waterline.

4.1.7 For passenger craft the following is also applicable:

(a) Gangway, cargo and service ports fitted below the margin line, *see* 1.2.2, are to satisfy the strength requirements given for side doors in this Section. They are to be effectively closed and secured watertight before the craft leaves port, and are to be kept closed during navigation. Such ports are not to have their lowest point below the deepest subdivision Load Line.

(b) Where the inboard end of a rubbish chute is below the margin line in a passenger craft, the inboard end cover is to be watertight and, in addition to the discharge flap interlock, a screwdown automatic non-return valve is to be fitted in an easily accessible position above the deepest subdivision. The valve is to be controlled from a position above the bulkhead deck and provided with an open/shut indicator, and kept closed when not in use. A suitable notice is to be displayed at the valve position.

4.1.8 Where doors and platforms are fitted in the shell, the structural and watertight integrity of the hull is to be maintained. Such doors and platforms are not to lead directly into the craft and an internal watertight compartment is to be provided in way of the shell openings. The doors and platforms are to be arranged to open outwards. The sill height of the access hull opening is not to be less than 300 mm above the waterline and the sill height of the internal access is to be not less than 300 mm higher than the hull sill. Alternative arrangements will be considered.

4.1.9 Doors may be of steel, aluminium alloy or FRP construction and are to be efficiently connected to the adjoining structure and of equivalent strength and are to have adequate securing and sealing arrangements. It is recommended that doors are hinged about their forward edges and open outwards. Details are to be submitted for approval. Other materials will be specially considered.

4.1.10 For craft complying with the requirements of this Section, the securing, supporting and locking devices are defined as follows:

(a) A securing device is used to keep the door closed by preventing it from rotating about its hinges or other pivoted attachments to the craft.

(b) A supporting device is used to transmit external and internal loads from the door to a securing device and from the securing device to the craft's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the craft's structure.

(c) A locking device locks a securing device in the closed position.

4.2 Symbols

4.2.1 The symbols used in this Section are defined as follows:

σ = bending stress, in N/mm^2

σ_e = equivalent stress, in N/mm^2

$= \sqrt{\sigma^2 + 3\tau^2}$

τ = shear stress, in N/mm^2

σ_o is defined in Ch 3,1.2.

4.3 Scantlings

4.3.1 In general the strength of side and stern doors is to be equivalent to the strength of the surrounding structure.

4.3.2 Door openings in the side shell are to have well rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below. *See* Ch 3,3 of Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively.

4.3.3 Doors are to be adequately stiffened, and means are to be provided to prevent movement of the doors when closed. Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the craft structure.

4.3.4 The thickness of the door plating is to be not less than the shell plating calculated with the door stiffener spacing, and in no case to be less than the minimum adjacent shell thickness.

4.3.5 Where stern doors are protected against direct wave impact by a permanent external ramp, the thickness of the stern door plating may be reduced by 20 per cent relative to the requirements of 4.3.4. Those parts of the stern door which are not protected by the ramp are to have the thickness of plating in full compliance with 4.3.4.

4.3.6 The section modulus of horizontal or vertical stiffeners is to be not less than required for the adjacent shell framing using the actual stiffener spacing. Consideration is to be given, where necessary, to differences in fixity between shell frames and door stiffeners.

4.3.7 Where necessary, door secondary stiffeners are to be supported by primary members constituting the main stiffening elements of the door.

4.3.8 The webs of primary members are to be adequately stiffened, preferably in a direction perpendicular to the shell plating.

4.3.9 The buckling strength of primary members is to be specially considered.

4.3.10 All load transmitting elements in the design load path from door through securing and supporting devices into the craft structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices.

4.4 Doors serving as ramps

4.4.1 Where doors also serve as vehicle ramps, the plating and stiffeners are to be not less than required for vehicle decks. *See* Ch 5,3 of Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively.

4.4.2 The design of the hinges for these doors is to take into account the craft angle of trim or heel which may result in uneven loading of the hinges.

4.5 Closing, securing and supporting of doors

4.5.1 Doors are to be fitted with adequate means of closing, securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is not generally to exceed 3 mm.

4.5.2 Securing devices are to be simple to operate and easily accessible. They are to be of an approved type.

4.5.3 Securing devices are to be equipped with mechanical locking arrangements (self locking or separate arrangements), or are to be of gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

4.5.4 Means are to be provided to enable the doors to be mechanically fixed in the open position taking into account the self weight of the door and a minimum wind pressure of 1,5 kN/m^2 (0,153 tonne-f/m^2) acting on the maximum projected area in the open position.

4.5.5 The spacing for cleats or closing devices is not to exceed 2,5 m and cleats or closing devices are to be positioned as close to the corners as practicable. Alternative arrangements for ensuring weathertight sealing will be specially considered.

4.5.6 Doors with a clear opening area of 12 m^2 or greater are to be provided with closing devices operable from a remote control position. Doors which are located partly or totally below the freeboard deck with a clear opening area greater than 6 m^2 are to be provided with an arrangement for remote control from a position above the freeboard deck. This remote control is provided for the:

(a) Closing and opening of the doors.
(b) Associated securing and locking devices.

4.5.7 The location of the remote control panel is to be such that the opening/closing operation can be easily observed by the operator or by other suitable means such as closed circuit television.

4.5.8 A notice is to be displayed at the operating panel stating that the door is to be fully closed and secured preferably before, or immediately prior to the craft leaving the berth and that this operation is to be entered in the craft's log. This notice is to be supplemented by warning indicator lights indicating if any door is not fully closed, secured and locked.

4.5.9 Means are to be provided to prevent unauthorized operation of the doors.

4.5.10 Where hydraulic securing devices are applied, the system is to be mechanically lockable in the closed position so that in the event of hydraulic system failure, the securing devices will remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in the closed position.

4.5.11 The design force considered for the scantlings of primary members, securing and supporting devices of side shell doors and stern doors are to be taken not less than:

(a) Design forces for securing or supporting devices of doors opening inwards:
External force:
$F_e = Ap_e + F_p$ kN
Internal force:
$P_i = P_o + 10W$ kN
(b) Design forces for securing or supporting devices of doors opening outwards:
External force:
$F_e = Ap_e$ kN
Internal force:
$P_i = P_o + 10W + F_p$ kN
(c) Design forces for primary members:
External force:
$F_e = Ap_e$ kN
Internal force:
$P_i = P_o + 10W$ kN

whichever is the greater.

The symbols used are defined as follows:

p_e = external sea pressure, not to be taken less than 25 kN/m^2
A = total area of door opening, in m^2, to be determined on the basis of the load area taking account of the direction of pressure
F_p = total packing force, kN. When packing is fitted, the packing force per unit length is to be specified, normally not to be taken less than: 5 kN/m
P_c = accidental force, in kN, due to loose cargo, etc., to be uniformly distributed over the area A and not to be taken less than 300 kN. For small doors such as bunker doors and pilot doors, the value of P_c may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental force due to loose cargoes
P_o = the greater of P_c and $5A$ kN
W = weight of the door, in tonnes.

4.6 Systems for indication and monitoring

4.6.1 The following requirements apply to doors in the boundaries of special category spaces or ro-ro spaces, as defined in the SOLAS Convention, through which such spaces may be flooded. For cargo craft, where no part of the door is below the uppermost waterline and the area of the door opening is not greater than 6 m^2, then the requirements of this Section need not be applied.

4.6.2 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to indicate that the doors are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator light.

4.6.3 The indicator system is to be designed on the fail safe principle and is to indicate by visual alarms if the door is not fully closed and not fully locked, and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors and is to be provided with a back-up power supply. The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.

4.6.4 The indication panel on the navigation bridge is to be equipped with a mode selection function 'harbour/sea voyage', so arranged that audible alarm is given if the craft leaves harbour with side shell or stern doors not closed or with any of the securing devices not in the correct position.

4.6.5 For passenger craft, a water leakage detection system with audible alarm and television surveillance are to be arranged to provide an indication to the navigation bridge and to the engine control room of any leakage through the doors. For cargo craft, a water leakage detection system with audible alarm is to be arranged to provide an indication to the navigation bridge.

Table 4.4.1 Permissible stress for bolts, closing and supporting devices

Material	Closing and supporting devices			Thread of bolts
	Direct stress N/mm^2	Shear stress N/mm^2	Equivalent stress N/mm^2	Direct stress N/mm^2
Steel	$\dfrac{120}{k_s}$	$\dfrac{80}{k_s}$	$\dfrac{150}{k_s}$	$\dfrac{120}{k_s}$
Aluminium	$\dfrac{64}{k_a}$	$\dfrac{43}{k_a}$	$\dfrac{80}{k_a}$	$\dfrac{64}{k_a}$

NOTES

1. $k_s = \dfrac{235}{\sigma_o}$, σ_o as defined in Ch 3,1.2.1
2. $k_a = \dfrac{120}{\sigma_{ya}}$, σ_{ya} as defined in Ch 3,1.2.2

4.7 Design of securing and supporting devices

4.7.1 Securing devices and supporting devices are to be designed to withstand the forces given in 4.5.11 using the permissible stresses given in Table 4.4.1. The terms 'securing device' and 'supporting device' are defined in Pt 6, Ch 5,4.3.

4.7.2 The nominal tensile stress in way of threads of bolts is not to exceed the permissible stress given in Table 4.4.1. The arrangement of securing and supporting devices is to be such that threaded bolts are not to carry support forces.

4.7.3 For steel to steel bearings in securing and supporting devices, the normal bearing pressure is not to exceed $0{,}8\sigma_o$. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification. The normal bearing pressure is to be calculated by dividing the design force by the projected bearing area.

4.7.4 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports. Small and/or flexible devices, such as cleats, intended to provide load compression of the packing material are not generally to be included in these calculations.

4.7.5 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be considered in the calculation of the reaction forces acting on the devices.

4.7.6 The number of securing and supporting devices is generally to be the minimum practicable whilst complying with 4.5.3 and taking account of the available space in the hull for adequate support.

4.7.7 The arrangement of securing devices and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces, without exceeding, by more than 20 per cent, the permissible stresses referred to in 4.7.1.

4.8 Operating and Maintenance Manual

4.8.1 An Operating and Maintenance Manual for the doors is to be provided on board and is to contain necessary information on:

(a) main particulars and design drawings;
(b) service conditions (e.g. service area restrictions, acceptable clearances for supports);
(c) maintenance and function testing;
(d) register of inspections and repairs.

This Manual is to be submitted for approval, and is to contain a note recommending that recorded inspections of the door supporting and securing devices be carried out by the craft's staff at monthly intervals or following incidents that could result in damage, including heavy weather or contact in the region of the doors. Any damages recorded during such inspections are to be reported to LR.

4.8.2 Documented operating procedures for closing and securing the doors are to be kept on board and posted at an appropriate place.

4.9 Engine removal arrangements

4.9.1 Where portable plates are required for unshipping machinery or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced structure and are secured by gaskets and closely spaced bolts. The pitch spacing of the bolts will be specially considered depending on the hatch stiffening and support arrangements but should not exceed ten diameters.

4.10 Testing on completion

4.10.1 The items listed in Table 1.7.1 in Chapter 1, are to be hose tested to the satisfaction of the Surveyor.

■ *Section 5*
Hatches on exposed decks

5.1 General

5.1.1 This Section applies to small hatchways or access openings in the positions indicated in Fig. 4.5.1.

5.1.2 The number and size of hatchways and other access openings are to be kept to the minimum consistent with the satisfactory operation of the craft.

5.1.3 Hatch covers are to be weathertight when closed, of substantial construction and generally hinged. The means of securing are to be such that weathertightness can be maintained in any sea condition. Details are to be submitted for approval.

5.1.4 Hatch covers may be of steel, aluminium alloy or FRP construction. Where toggles are fitted, their diameter and spacing are to be in accordance with an ISO standard or equivalent.

5.1.5 Hatches on the weatherdeck in the forward 0,25L_R or to machinery spaces are to be hinged on the forward side.

5.2 Coaming heights

5.2.1 Hatch coamings are to have a height above the deck surface in accordance with Table 4.5.1. Lower heights may be considered in relation to operational requirements and the nature of the spaces to which access is given.

5.2.2 Flush hatches will be specially considered.

5.2.3 Rope hatches may be accepted with reduced coamings, but generally not less than 380 mm, provided they are well secured and opened only at the Master's discretion. A suitable notice is to be displayed at the hatch.

5.3 Scantlings

5.3.1 Hatch covers are to be of equivalent strength to the deck on which they are fitted.

Table 4.5.1 Height of hatch coamings

Location/Access	Height (mm) (*see* Note 2)
(a) Weather deck/machinery compartment	460
(b) Weather deck/lower deck accommodation	230
(c) Weather deck/cargo hold	460

NOTES
1. For locations (a) and (b), *see* Fig. 4.5.1.
2. Reduced coaming heights will be specially considered based on a craft's service area restriction notation.

5.3.2 The thickness of the coamings is to be not less than the Rule thickness for the deck in the positions in which they are fitted. Stiffening of the coaming is to be appropriate to its length and height.

5.3.3 The covers are to be adequately stiffened.

5.4 Closing devices

5.4.1 Hinges are not to be used as securing devices unless specially considered.

5.4.2 Escape hatches are to be capable of being opened from either side.

5.5 Engine removal hatches

5.5.1 Where portable plates are required in decks for unshipping machinery or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced deck and are secured by gaskets and closely spaced bolts. The pitch spacing of the bolts will be specially considered depending on the hatch stiffening and support arrangements but should not exceed ten diameters.

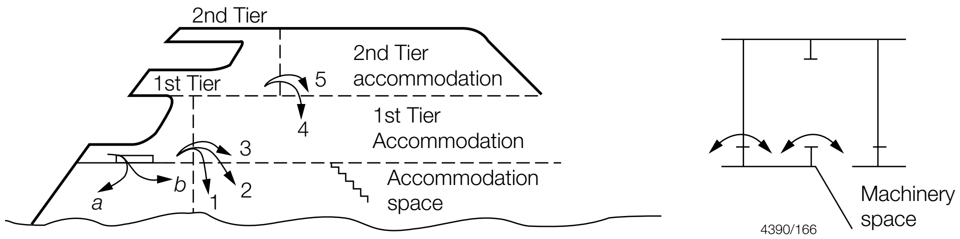


Fig. 4.5.1 Arrangement of doors, sills and hatch coamings

5.6 Structural details

5.6.1 Various structural details for hatchways and access openings are given in the LR *Guidance Notes for Structural Details.*

5.7 Effective support for large hatch covers

5.7.1 The weight of hatch covers and any loads carried thereon, together with inertial forces generated by craft motions, are to be effectively transmitted to the craft structure. This may be achieved by continuous structural contact of the hatch cover with the craft structure or by means of defined bearing pads. The bearing pressure will be specially considered depending on the construction material.

5.8 National Authority requirements

5.8.1 The height of the hatch coaming may be subject to additional requirements of the National Authority.

5.9 Exceptions

5.9.1 Subject to the agreement of LR exceptions may be given to the requirements of this Section where they interfere with the operation of the craft. Such exceptions will be specially considered.

5.10 Testing upon completion

5.10.1 The items listed in Table 1.7.1 in Chapter 1, are to be hose tested to the satisfaction of the Surveyor.

5.11 Standard designs

5.11.1 Standard designs of hatches may be accepted, provided they are designed and manufactured in accordance with the requirements of a recognised National or International Standard which gives reasonable equivalence to the requirements of this Section.

5.11.2 Standard proprietary flush hatches, not exceeding 650 mm x 650 mm clear opening, which are of a type holding a valid Type Approval by LR, may be accepted for under deck access in non-working areas of craft below 24 m in length, L_R, dependent upon the Service Group Notation. Where the hatch type is not type approved, full details, including the material specification, are to be submitted for approval in each case.

5.12 Novel features

5.12.1 Hatchways of novel or unusual design will be specially considered.

■ *Section 6* Miscellaneous openings

6.1 General

6.1.1 This Section gives requirements for external doors, manholes and flush scuttles, hatchways within enclosed superstructures or ’tween decks and companionways, doors and accesses on weather decks.

6.1.2 Those items listed in Table 1.7.1 in Chapter 1, are to be hose tested to the satisfaction of the Surveyor.

6.2 External doors

6.2.1 Door sills are to have a height above the deck surface in accordance with Table 4.6.1.

Table 4.6.1 Height of door sills

Position/access	Height (mm)
(1) Weather deck/machinery compartment (*See* Note 2)	460
(2) Weather deck/lower accommodation	230
(3) Weather deck/1st tier accommodation	150
(4) 1st tier/1st tier accommodation	100
(5) 1st tier/2nd tier accommodation	50

NOTES
1. For positions (1), (2), etc., *see* Fig. 4.5.1
2. Where the access to the machinery space is protected by an outer weathertight door, the inner door sill or hatch coaming may be 230 mm high in association with an outer sill height of 230 mm.

6.2.2 Reduced sill heights for doors will be considered as follows:
(a) dependent upon the service group notation,
(b) for doors which will only be used when the craft is in harbour, or calm water,
(c) where the sill height interferes with the operation of the craft,
(d) where doors do not give access to spaces below the freeboard deck.

6.2.3 The height of the door sill may be subject to additional requirements of the National Authorities.

6.2.4 Where the sill heights do not comply with the requirements of Table 4.6.1, interior deck openings are to be treated as if they were exposed on the weather deck.

6.3 Manholes and flush scuttles

6.3.1 Manholes and flush scuttles fitted in Positions 1 and 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

6.4 Hatchways within enclosed superstructures or 'tween decks

6.4.1 The requirements of Section 5 are to be complied with where applicable.

6.4.2 Access hatches within a superstructure or deckhouse in Position 1 or 2 need not be provided with means for closing if all openings in the surrounding bulkheads have weathertight closing appliances.

6.5 Companionways, doors and accesses on weather decks

6.5.1 Companionways on exposed decks are to be of equivalent construction, weathertightness and strength to a deckhouse in the same position and effectively secured to the deck.

6.5.2 Access openings in:

(a) Bulkheads at ends of enclosed superstructures,

(b) Deckhouses or companionways protecting openings leading into enclosed superstructures or to spaces below the freeboard deck, and

(c) Deckhouses on a deckhouse protecting an opening leading to a space below the freeboard deck,

may be fitted with doors of steel, aluminium alloy, FRP or other equivalent material, permanently and strongly attached to the bulkhead and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead, and weathertight when closed. The doors are to be gasketed and secured weathertight by means of clamping devices or equivalent arrangements, permanently attached to the bulkhead or to the door. Doors are generally to open outwards and are to be capable of being operated and secured from both sides. The sill heights are to be as required by 6.2. Double doors are to be equivalent in strength to the unpierced bulkhead, and in Position 1, a centre pillar is to be provided which may be portable.

6.5.3 Elsewhere doors may be of hardwood or equivalent material and are to be of equivalent strength to the unpierced bulkhead.

6.5.4 Portlights or windows in doors are to comply with the requirements given in Section 7. Deadlights or storm covers may be external.

6.5.5 When the closing appliances of openings in superstructures and deckhouses do not comply with 6.5.2, interior deck openings are to be treated as if exposed on the weather deck.

6.5.6 Doors on the weather deck (first tier) protecting direct access to machinery spaces are to be of substantial construction in accordance with approved plans or a recognised National or International Standard. They are to be permanently attached to the casing, outward opening and gasketed weathertight with a minimum of six clips and have a sill height in accordance with 6.2.

6.5.7 Doors on the weather deck to accommodation or spaces protecting access below are to be as required by 6.5.6 with a minimum of four clips.

6.5.8 Where wood doors are proposed on the weather deck in lieu of doors as per 6.5.7, they are to be strongly constructed of hardwood not less than 45 mm thick and double gasketed. For doors in exposed locations, additional securing arrangements by slip bolts, clamps or equivalent will be required. These doors are not to be the sole means of entry or exit from the space. Where these doors may be required to be used as a means of escape in an emergency situation, the additional security arrangements are to be operable from both sides.

6.5.9 FRP doors are not to be fitted in access openings where 'A', 'B' or 'C' class fire integrity is required, or in engine room casings.

6.5.10 Doors in the second tier are to be as required by 6.5.6 with a minimum of four clips.

■ *Section 7*
Portlights, windows and viewing ports, skylights and glass walls

7.1 General

7.1.1 This Section gives the requirements for portlights, windows, viewing ports, sliding glass doors, glass walls, skylights, glazing materials, deadlights and storm covers.

7.1.2 Side scuttles and portholes are considered to be portlights.

7.1.3 A plan showing the location of portlights, windows, viewing ports, skylights and glass walls is to be submitted.

7.1.4 Portlights and windows, together with their glazing and deadlights if required, are to be of an approved design or in accordance with a recognised National or International Standard.

7.1.5 Glass in portlights, windows and skylights is to be thermally toughened safety glass with a thickness in accordance with approved plans or a recognised National or International Standard relative to their location.

7.1.6 Where consideration is given to the use of glazing materials other than thermally toughened glass, the thickness and arrangements are to take account of any different material properties and be approved.

7.1.7 The acceptance of 'glued-in' glazing material, when proposed, will be subject to Type Approval or individual approval and tests as appropriate.

7.1.8 The use of rubber frames is not generally acceptable.

7.1.9 In position 2, cabin bulkheads and doors are considered effective between portlights or windows and access below.

7.1.10 Side scuttles are defined as being round or oval openings with an area not exceeding 0,16 m^2. Round or oval openings having areas exceeding 0,16 m^2 shall be treated as windows.

7.1.11 Windows are defined as being rectangular openings generally, having a radius at each corner relative to the window size and round or oval openings with an area exceeding 0,16 m^2.

7.2 Applications

7.2.1 As indicated in 1.1. *See also* Part 4 for additional requirements for yachts.

7.3 National Authority requirements

7.3.1 In addition to the requirements of this Section, where relevant, care is to be given to the statutory requirements of the National Authority.

7.4 Portlights

7.4.1 Portlights are to be in accordance with a recognised National or International Standard or of a type accepted for the respective position and having a valid LR Type Approval certificate. Where the portlight is not type approved, full details are to be sumitted for approval in each case.

7.4.2 Portlights may be round, elliptical or elongated and are to be of substantial construction

7.4.3 Portlights are not to be fitted in machinery spaces.

7.4.4 No portlight is to be fitted in such a position that its still is below a line drawn parallel to the freeboard deck at side and having its lowest point 2,5 per cent of the breadth, *B,* above the load waterline corresponding to the summer freeboard (as defined in Ch 1,6.2.7), or 500 mm, whichever is the greater distance. (*see* Fig. 4.7.1)

7.4.5 Deadlights or storm covers for portlights are to be provided in accordance with 7.12.

7.5 Windows

7.5.1 Windows are to be in accordance with a recognised National or International Standard or of a type accepted for the respective position and having a valid LR Type Approval certificate.

7.5.2 Where the window is not type approved, full details are to be submitted for approval in each case and the prototype tested in accordance with the requirements of 7.5.3 to 7.5.5.

7.5.3 A hydrostatic test is to be carried out in order to examine watertightness. A design pressure p, where p is given in 7.8.1 is to be applied and maintained for at least 15 minutes.

7.5.4 A hydrostatic test is to be carried out in order to examine the capability of the frame, and glass retaining arrangements. A design pressure 4p, where p is given in 7.8.1 is to be applied. Alternatively this test may be carried out using a steel plate in place of the glass. Ideally the steel plate thickness should be of a suitable reduced thickness to simulate the flexural performance of the glass.

7.5.5 Equivalent proposals for testing will be considered. Where alternative testing procedures are proposed, these are to be agreed with LR before commencement.

7.5.6 Window glazing is, in general, to be toughened safety glass, fitted in substantial frames supporting both faces of the glass and effectively secured to the structure. Metal to glass contact is to be avoided.

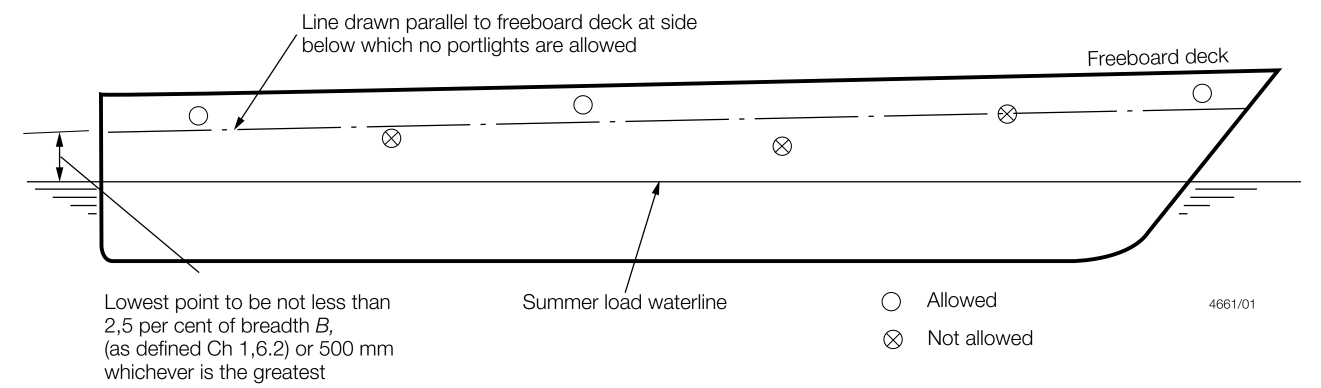


Fig. 4.7.1 Position of portlights

7.5.7 In general, no windows are to be fitted in the following locations:

(a) below the freeboard deck;

(b) in the first tier end bulkheads or sides of enclosed superstructures; or

(c) in first tier deckhouses that are considered buoyant in the stability calculations.

7.5.8 Wheelhouse window glazing is to be toughened safety glass, or where it is of laminated or sandwich construction, the surface layers are to be of toughened safety glass.

7.5.9 Large windows in the aft end of superstructure or deckhouses will be specially considered.

7.5.10 Openings in the shell for windows are to have well rounded corners.

7.5.11 Storm covers or deadlights for windows are to be provided in accordance with 7.12.

7.6 Viewing ports

7.6.1 In general, viewing ports are not to be fitted in the bottom shell of high speed craft.

7.6.2 Viewing ports are to be watertight and of substantial construction in accordance with approved plans.

7.6.3 Glazing is to be fitted in substantial frames supporting both faces of the glazing and effectively secured to the hull structure.

7.6.4 Where practicable, viewing ports are to be fitted with efficient, hinged, deadlights which are capable of being effectively closed and secured watertight, with or without the glazing in place.

7.6.5 Hydrostatic pressure tests are to be carried out to confirm that the proposed construction, when fitted in the hull, is able to withstand a pressure of four times the design pressure and remain watertight. Where a deadlight is fitted, this test is also to be carried out with the glazing removed and the deadlight closed.

7.7 Sliding glass doors or 'glass walls'

7.7.1 Large glass doors or windows in the aft end of superstructures and deckhouses and other large glass structures forming the sides, ends or roofs of deckhouses will be specially considered.

7.7.2 When sliding glass doors are provided, or a 'glass wall' which includes an access, an alternative access or exit from the space is to be provided and the arrangements are to be in accordance with approved plans and weathertight commensurate with their position. Sill heights are, in general, to be in accordance with 6.2.

7.7.3 The glazing is to be toughened safety glass, or equivalent, and of substantial thickness in accordance with 7.8, 7.9 or 7.10 as appropriate.

7.7.4 Storm covers or roller shutters are to be provided in accordance with 7.12.11.

7.8 Toughened safety glass thickness

7.8.1 The thickness, t, of toughened safety glass is to be not less than 6 mm or that given by the following expression, whichever is the greater:

for glazing of rectangular form

$$t = 0{,}005b\sqrt{\beta p} \text{ mm}$$

for glazing of circular form

$$t = 0{,}00559r\sqrt{p} \text{ mm}$$

where

a = length of longer side of window, in mm

b = length of shorter side of glazing, in mm

p = design pressure in kN/m^2, as defined in Pt 5, Ch 3,3.1 and Ch 4,3.1

r = radius of the glazing, in mm

A_R = aspect ratio of window = a/b

β = $-0{,}17 + 0{,}54A_R - 0{,}078A_R^2$ for $A_R \le 3$

= 0,75 for $A_R > 3$.

7.8.2 For windows of trapezoidal form, the length of window, a, is to be taken as the mean of the length of the longer sides. The value of b, the length of the shorter side, may be similarly determined.

7.9 Laminated glass thickness

7.9.1 Laminated toughened safety glass may be used having a thickness greater than the single plate toughened safety glass for the same size window, as given by:

$$t_s^2 = t_{i1}^2 + t_{i2}^2 + \ldots\ldots + t_{in}^2 \text{ mm}$$

where

n = number of laminates

t_i = thickness of laminate, in mm

t_s = thickness of equivalent single plate, in mm.

7.10 Other glazing materials

7.10.1 Materials other than glass may be used for windows, except for those in the wheelhouse, with the thickness obtained by multiplying the thickness for toughened safety glass by a factor of 1,3 for polycarbonate and 1,5 for acrylic. Consideration will be given to composite and multi-layer constructions where documented results of a pressure test confirm that the proposed construction, when fitted in its appropriate frame, is able to withstand a test pressure of four times the design pressure and remain watertight.

7.11 Openings and framing requirements

7.11.1 The strength and dimensions of the frame section are to be appropriate to the size of the window, the type of glazing being used and its method of bedding. The glazing is to be secured to its frame in accordance with the Manufacturer's instructions and recommendations; metal to glass contact is to be avoided.

7.11.2 Rubber frames are not acceptable for windows in Positions 1 and 2, and are not generally acceptable in any other position in external casings. Any proposals to fit rubber frames are to be submitted for consideration. The proposed locations, frame dimensions, glass thicknesses and the results of any tests carried out, are to be forwarded.

7.12 Deadlights and storm covers

7.12.1 Portlights fitted to spaces below the weather deck, or to spaces within enclosed superstructures, are to be fitted with efficient, hinged, inside deadlights which are capable of being effectively closed and secured watertight below the weather deck and weathertight above the weather deck.

7.12.2 In service craft less than 24 m Rule length, L_R, and yachts, portlights in the hull in way of accommodation may have portable deadlights, provided that they are stored adjacent to the portlight and can be readily fitted. Also, in the case of these craft, portlights in superstructures or deckhouses do not require to have deadlights, unless on the weather deck in exposed positions or protecting direct access below, in which case, they are to be provided with deadlights or storm covers.

7.12.3 For craft in **Service Group G1**, storm covers or deadlights are generally not required for windows or portlights in superstructures or deckhouses.

7.12.4 For craft in **Service Group G2**, storm covers or deadlights are required for:

(a) 50 per cent of the windows and portlights in the front of the superstructure or deckhouse on the weather deck.

(b) The windows and portlights in the forward half of the superstructure or deckhouse side on the weather deck, except where these are interchangeable port and starboard, in which case a sufficient number to fit the forward half of one side is to be provided.

(c) Each different size of window and portlight.

7.12.5 For craft in **Service Group G3**, storm covers or deadlights are required for:

(a) All windows and portlights in the front of the superstructure or deckhouse on the weather deck.

(b) All windows and portlights in the sides of the superstructure or deckhouse on the weather deck, except where they are interchangeable port and starboard, in which case a sufficient number to fit any one side are to be provided.

(c) Each different size of window and portlight.

7.12.6 For craft in **Service Groups G4** and **G5**, storm covers or deadlights are required as follows:

(a) If fitted in a deckhouse in Position 1, windows are to be provided with strong, hinged, weathertight storm covers. However, if there is an opening leading below deck in this deckhouse, this opening is to be treated as being on an exposed deck and is to have weathertight protection.

(b) Portlights and windows at the shell in Position 2, protecting direct access below, are to be provided with strong permanently attached deadlights.

(c) Portlights and windows at the shell in Position 2, not protecting direct access below, are to be provided with strong portable steel covers for 50 per cent of each size, with means for securing at each window.

(d) Portlights and windows set inboard from the shell in Position 2, protecting direct access below, are either to be provided with strong permanently attached deadlights or, where they are accessible, strong permanently attached external storm covers instead or internal deadlights.

(e) Portlights and windows set inboard from the shell in Position 2, not protecting direct access below, do not require deadlights or storm covers.

(f) Windows in the shell above Position 2 are to be provided with strong portable internal storm covers for 25 per cent of each window, with means of securing being provided at each window.

(g) Where windows are permitted in an exposed bulkhead on the weather deck in the forward $0,25L_L$, strong external storm covers are to be provided, which may be portable and stored adjacent.

7.12.7 Deadlights and storm covers are not required for second tier portlights or windows in deckhouses without direct access below.

7.12.8 Where the wheelhouse is in Position 2, in lieu of storm covers being provided for the wheelhouse windows, a weathertight cover, fitted to a coaming of not less than 230 mm in height around the internal stairway opening within the wheelhouse, may be accepted. If this arrangement is accepted, adequate means of draining the wheelhouse are to be provided.

7.12.9 If necessary, for practical considerations, the storm covers may be in two parts.

7.12.10 Deckhouses situated on a raised quarter deck may be treated as being in Position 2 as far as the provision of deadlights is concerned, provided the height of the raised quarter deck is equal to, or greater than the standard height.

7.12.11 Sliding glass doors are to be provided with storm covers of strong construction, or, in the case of a 'glass wall', this may be protected by a strongly constructed roller shutter or equivalent, which can be readily lowered and secured to provide adequate protection. When necessary, additional portable supports are to be provided for the cover. The arrangements are to be in accordance with approved plans. Alternative arrangements will be specially considered. In lieu of a weathertight coaming for the cover, adequate drainage is to be provided between the cover and the glass which may be in the form of a sump drained overboard, with a grating over.

7.12.12 Deadlights and storm covers are to be weathertight and of equivalent strength to the surrounding structure.

7.12.13 Portable deadlights and storm covers are to be clearly marked to indicate which portlights or windows they fit and stowed in such a way as to be readily fitted.

7.13 Emergency exits

7.13.1 Portlights or windows intended as emergency escapes are to be capable of being opened from both sides and have a minimum clear opening of 600 mm x 600 mm.

7.14 Skylights

7.14.1 Skylights, where fitted, are to be of substantial construction and securely attached to their coamings. The height of the lower edge of opening is to be as required by 5.2.1. The scantlings of the coaming are to be as required by 5.3.2. The thickness of glasses in fixed or opening skylights is to be appropriate to their size and position as required for portlights or windows. Glasses in any position are to be protected from mechanical damage, and where fitted in Positions 1 or 2 (as defined in Ch 1,6.10) are to be provided with robust deadlights or storm covers permanently attached.

7.15 Testing on completion and installation

7.15.1 In order to demonstrate that the requirements of this Section are met the closing arrangements are to be operated under working conditions to the satisfaction of the Surveyor.

7.15.2 The items listed in Table 1.7.1, in Chapter 1, are to be hose tested to the satisfaction of the Surveyor.

■ *Section 8*
Bulwarks, guard rails and other means for the protection of crew

8.1 General

8.1.1 Bulwarks or guard rails are to be provided at the boundaries of exposed freeboard and superstructure decks and first tier deckhouses. Bulwarks or guard rails are to be not less than 1,0 m in height measured above sheathing, and are to be constructed as required by 8.2 and 8.4 respectively. Special consideration will be given to cases where this height would interfere with the normal operation of the craft.

8.1.2 The freeing arrangements in bulwarks are to be in accordance with Section 9.

8.1.3 Where appropriate, special consideration will be given to the provision of guard-wires in lieu of bulwarks or guard rails.

8.1.4 Where wire ropes are fitted, adequate devices are to be provided to ensure their tautness.

8.1.5 Where stanchions are fitted, every third stanchion is to be supported by a bracket or stay.

8.1.6 A proper step arrangement is to be provided in way of obstructions such as pipe lines, etc.

8.2 Bulwark construction

8.2.1 Plate bulwarks are to be stiffened by a strong rail section and supported by stays from the deck. The spacing of these bulwark stays is not to be greater than 1,83 m. Where bulwarks are cut to form a gangway or other opening, stays of increased strength are to be fitted at the ends of the openings. Bulwarks are to be adequately strengthened in way of eyeplates for cargo gear, and in way of mooring pipes the plating is to be doubled or increased in thickness and adequately stiffened.

8.2.2 In the calculation of the section modulus, only the material connected to the deck is to be included. The bulb or flange of the stay may be taken into account where connected to the deck, and where, at the ends of the craft, the bulwark plating is connected to the sheerstrake, a width of plating not exceeding that considered effective (*see* Pt 6, Ch 3,1.10, Pt 7, Ch 3,1.11 and Pt 8, Ch 3,1.7 for steel, aluminium alloy and composite construction respectively) may also be included. The free edge of the stay is to be stiffened.

8.2.3 Bulwark stays are to be supported by, or to be in line with, suitable underdeck stiffening, which is to be connected by double continuous fillet welds in way of the bulwark stay connection.

8.2.4 The foregoing requirements do not allow for any loading from deck cargoes.

8.3 Openings in bulwarks

8.3.1 Bulwarks are not to be cut for gangway or other openings near the breaks of superstructures, and are also to be arranged to ensure their freedom from main structural stresses. *See* shell plating in appropriate Chapters.

8.4 Guard rails

8.4.1 The opening below the lowest course of guardrails is not to exceed 230 mm. The other courses are to be spaced not more than 380 mm apart. In the case of craft with rounded gunwales, the guard rail supports are to be placed on the flat of the deck.

8.4.2 Satisfactory means, in the form of guard rails, life-lines, handrails, gangways, underdeck passageways or other equivalent arrangements, are to be provided for the protection of the crew in getting to and from their quarters, the machinery space and all other parts used in the necessary work of the craft.

8.4.3 Chains are only permitted in short lengths in way of access openings.

8.4.4 Where permitted by the National Authority, gangways or walkways may be omitted on craft operating within **Service Groups G1** or **G2**. However, lifelines are to be provided on flush deck craft, or where the cargo hatch coamings are less than 600 mm high.

■ *Section 9* Deck drainage

9.1 General

9.1.1 Where bulwarks on the weather portions of freeboard or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of large quantities of water by means of freeing ports, and also for draining them.

9.2 Freeing port area

9.2.1 The minimum freeing area on each side of the craft for each well on the freeboard deck or raised quarter deck, where the sheer in the well is not less than the standard sheer required by the *International Convention on Load Lines*, 1966, is to be derived from the following formulae:

(a) where the length, l, of the bulwark in the well is 20 m or less:
area required = $0,7 + 0,035l$ m^2

(b) where the length, l, exceeds 20 m
area required = $0,07l$ m^2
l need not be taken greater than $0,7L_L$, where L_L is the length of the craft as defined in Ch 1,6.2.

9.2.2 If the average height of the bulwark exceeds 1,2 m or is less than 0,9 m, the freeing area is to be increased or decreased, respectively, by 0,004 m^2 per metre of length of well for each 0,1 m increase or decrease in height respectively.

9.2.3 The minimum freeing area for each well on a first tier superstructure is to be half the area calculated from 9.2.1.

9.2.4 Two-thirds of the freeing port area required is to be provided in the half of the well nearest to the lowest point of the sheer curve.

9.2.5 When the deck has no sheer, the minimum freeing area for each well calculated from 9.2.1 is to be increased by 50 per cent. Where the sheer is less than the standard the percentage shall be obtained by linear interpolation. The freeing area is to be spread along the length of the well.

9.2.6 Where the length of the well is less than 10 m, or where a deckhouse occupies most of the length, the freeing port area will be specially considered but in general need not exceed ten per cent of the bulwark area.

9.2.7 Where it is not practical to provide sufficient freeing port area in the bulwark, particularly in small craft, credit can be given for bollard and fairlead openings where these extend to the deck.

9.2.8 Where a craft fitted with bulwarks has a continuous trunk, or hatch side coamings that are continuous, or substantially continuous, the minimum freeing area is to be not less than 20 per cent of the total bulwark area where the width of trunk or hatchway is 0,4*B* or less, and not less than 10 per cent of the total bulwark area when the width of the trunk or hatch is 0,75*B* or greater. The freeing area required for an intermediate width of trunk or hatch is to be obtained by linear interpolation.

9.2.9 Where the trunk referred to in 9.2.8 or its equivalent is included in the calculation of freeboard, open rails are to be fitted for at least 50 per cent of the length of the exposed part of the weather deck. Alternatively, if a continuous bulwark is fitted, the minimum freeing area is to be at least 33 per cent of the bulwark area. The freeing area is to be placed in the lower part of the bulwark.

9.2.10 Where a deckhouse has a breadth less than 80 per cent of the beam of the craft, or the width of the side passageways exceed 1,5 m, the arrangement is considered as one well. Where a deckhouse has a breadth equal to or greater than 80 per cent of the beam of the craft, or the width of the side passageways does not exceed 1,5 m, or when a screen bulkhead is fitted across the full breadth of the craft, this arrangement is considered as two wells, before and abaft the deckhouse.

9.2.11 Adequate provision is to be made for freeing water from superstructures which are open at either or both ends and from all other decks within open or partially open spaces in which water may be shipped and contained.

9.2.12 Suitable provision is also to be made for the rapid freeing of water from recesses formed by superstructures, deckhouses and deck cargo arrangements, etc., in which water may be shipped and trapped. Deck gear, particularly on fishing craft, is not to be stowed in such a manner as to obstruct unduly the flow of water to freeing ports.

9.2.13 The lower edges of freeing ports are to be as near to the deck as practicable, and should not be more than 100 mm above the deck.

9.3 Free flow area

9.3.1 The effectiveness of the freeing port area in bulwarks of craft not fitted with a continuous deck obstruction, depends on the free flow across the deck.

9.3.2 The free flow area is the net total longitudinal area of the transverse passageways or gaps between hatchways and superstructures or deckhouses, due account being made for any obstructions such as equipment or other fittings. The height of passageways or gaps used in the calculation of the area is the height of the bulwark.

9.3.3 The provision of freeing area in bulwarks is to be related to the net free flow area as follows:

(a) If the free flow area is equal to, or greater than the freeing port area calculated from 9.2.8 when the hatchway coamings are continuous, then the minimum freeing area calculated from 9.2.1 is sufficient.

(b) If the free flow area is less than the freeing port area calculated from 9.2.1, then the minimum freeing area is to be that calculated from 9.2.8.

(c) If the free flow area is less than the freeing port area derived from (a) but greater than that derived from (b), the minimum freeing area, F, in the bulwark is to be obtained from the following formula:

$$F = F_1 + F_2 - f_p \quad \text{m}^2$$

where

F_1 = minimum area from 9.2.1

F_2 = minimum area from 9.2.8

f_p = total net area of passages and gaps between hatchways, superstructures and deckhouses (the free flow area).

9.4 Scupper arrangements

9.4.1 Scuppers, sufficient in number and size to provide effective drainage, are to be fitted in all decks.

9.4.2 Scuppers draining weather decks and spaces within superstructures or deckhouses not fitted with efficient weathertight doors are to be led overboard.

9.4.3 Scuppers and discharges which drain spaces below the freeboard deck, or spaces within intact superstructures or deckhouses on the freeboard deck fitted with efficient weathertight doors, may be led to the bilges in the case of scuppers, or to suitable sanitary tanks in the case of sanitary discharges. Alternatively, they may be led overboard provided that:

(a) the freeboard is such that the deck edge is not immersed when the craft heels to 5°, and

(b) the scuppers are fitted with a positive control valve or automatic non-return valve at the shell preventing water from passing inboard.

9.4.4 In craft where an approved fixed pressure water spray fire-extinguishing system is fitted in vehicle or cargo spaces, deck scuppers of not less than 150 mm diameter are to be provided port and starboard, spaced about 9,0 m apart. The scupper area will require to be increased if the design capacity of the drencher system exceeds the Rule required capacity by 10 per cent or more. After installation, the two adjacent sections with the greatest aggregate drencher capacity are to be tested in operation to ensure that there is no build up of water on the deck. The scuppers are to be led inboard to tanks or, alternatively they may be led overboard providing they comply with 9.4.3(a) and (b). Inboard draining scuppers do not require valves but are to be led to suitable drain tanks (water contaminated with petrol or other flammable substance is not to be drained to machinery spaces or any other space where a source of ignition may be present) and the capacity of the tanks is to be sufficient to hold approximately 10 minutes of drenching water. The arrangements for emptying these tanks are to be approved and suitable high level alarms provided. The mouth of the scupper is to be protected by bars.

9.4.5 Scupper pipes from the weather decks discharging overboard below or near the waterline are to be provided with a non-return valve or positive control valve. Where the scupper pipes are of substantial construction, having a wall thickness of not less than that of the side shell plus 2 mm, the non-return valve or positive control valve may be omitted.

9.4.6 For the use of non-metallic pipe, *see* Pt 15, Ch 1,8.

9.5 Large freeing port openings

9.5.1 Where the height of freeing ports is greater than 230 mm, vertical bars spaced approximately 230 mm apart may be accepted, as an alternative to a horizontal rail, to limit the height of the freeing port. Other equivalent arrangements will be specially considered.

■ *Section 10* **Cabin sole and lining**

10.1 General

10.1.1 Cabin soles are to be fitted and secured in such a manner as to provide access to the structure and fittings below.

10.1.2 The cabin fittings and linings against the side of the craft are to be so fitted as to be capable of being removed when necessary. The method of attachment is not to impair the strength of the structural members.

10.1.3 For fire protection requirements for cabin fittings and linings, *see* Part 17.

10.2 Removal for access

10.2.1 It is recommended that the cabin fittings and linings against the side of the craft be so fitted as to be capable of being removed when necessary. The method of attachment is not to impair the strength of the structural members.

10.3 Fire aspects

10.3.1 For information and plans required, *see* Part 17.

■ *Section 11* **Ventilators**

11.1 General

11.1.1 This Section provides requirements for ventilators and the ventilation of all craft.

11.1.2 The requirements conform, where relevant, with those of the *International Convention on Load Lines, 1966*. Reference is also to be made to any additional requirements of the National Authority of the country in which the craft is to be registered and to the relevant regulations of the *International Convention for the Safety of Life at Sea, 1974* and applicable amendments.

11.1.3 Special care is to be taken in the design and positioning of ventilator openings and coamings, particularly in the region of the forward end of superstructures and other points of high stress. The deck plating in way of the coamings is to be efficiently stiffened.

11.1.4 The scantlings of ventilators exposed to the weather are to be equivalent to those of the adjacent deck or bulkhead. Where the height of the ventilator exceeds that required by 11.5.1, the thickness may be gradually reduced above that height to a minimum which will be specially considered dependent on the material of construction. Ventilators are to be adequately stayed.

11.1.5 Ventilators from deep tanks and tunnels passing through 'tween decks are to have scantlings suitable for withstanding the pressures to which they may be subjected, and are to be made watertight.

11.1.6 For the requirements for fire precautions on cargo and passenger craft, *see* Part 17.

11.1.7 Adequate ventilation is to be provided throughout the craft.

11.1.8 For the requirements for yachts, *see also* Part 4.

11.2 Accommodation spaces

11.2.1 Accommodation spaces are to be protected from gas or vapour fumes from machinery, exhaust and fuel systems in accordance with Ch 2,4.7, *see also* Part 17.

11.3 Machinery spaces

11.3.1 In addition to the requirements of this Section, a filter coalescer is to be fitted to the machinery space air intakes to remove fine spray where:

- Intakes are fitted in exposed positions on the weather deck; or
- intakes are large; or
- coaming height is reduced; or
- as required by the engine manufacturer.

Special consideration will be given to alternative arrangements for craft operating within service groups G1–G3, *see also* Part 9.

11.3.2 In general, ventilators necessary to continuously supply the machinery space or the emergency generator room shall have coamings of sufficient height to comply with 11.4.1, without having to fit weathertight closing appliances.

11.3.3 Where it is not practical to comply with 11.3.2 due to ship size and arrangement, lesser heights for machinery space and emergency generator room ventilator coamings, fitted with weathertight closing may be permitted by the Administration in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of ventilation to these spaces.

11.4 Closing appliances

11.4.1 All ventilator openings are to be provided with efficient weathertight closing appliances unless:

(a) The height of the coaming is greater than 4,5 m above the deck at Position 1.
(b) The height of the coaming is greater than 2,3 m above the deck at Position 2.

11.4.2 Closing appliances are to be permanently attached to the ventilator coaming.

11.4.3 Where, in ferries, ventilators are proposed to be led overboard in an enclosed 'tween deck, the closing arrangements are to be submitted for approval. If such ventilators are led overboard more than 4,5 m above the main vehicle deck, closing appliances may be omitted, provided that satisfactory baffles and drainage arrangements are provided, as in the case of air intakes or exhaust openings for machinery spaces, which may be arranged in the sides of the craft.

11.4.4 Mushroom ventilators closed by a head revolving on a centre spindle (screw down head) are acceptable in Position 2, and also in sheltered positions in Position 1, but the diameter is not to exceed 300 mm if situated within the forward $0,25L_L$.

11.4.5 Mushroom ventilators with a fixed head and closed by a screw down plate (screw down cover) may be accepted in exposed positions within the forward $0,25L_L$ up to a diameter of 750 mm.

11.4.6 Wall ventilators (jalousies) may be accepted provided they are capable of being closed weathertight by hinged gasketed covers secured by bolts or toggles. They are preferably to face aft or athwartships and are to be fitted with a suitable means of preventing ingress of water and spray when open in the form of louvres, baffles, screens or an equivalent arrangement.

11.4.7 Reference is to be made to Section 1 concerning down flooding through ventilators which do not require closing appliances due to their coaming height being in accordance with 11.4.1.

11.5 Effective coaming heights

11.5.1 The height of ventilator coamings exposed to the weather is to be as high as practicable, with a minimum height of 600 mm in Position 1 and 450 mm in Position 2. In particularly exposed positions, the height of coamings may be required to be increased or self closing devices may be required.

11.5.2 Reduced coaming heights may be considered for ventilators which are not required for the operation of the craft at sea, provided that operational procedures are in place and a notice is fitted to the ventilator to ensure that the closing device is closed whilst the craft is at sea.

11.5.3 For gooseneck ventilators, the coaming height is to be measured to the underside of the bend, this being the lowest point through which water on deck could pass freely to spaces below.

11.5.4 Where wall ventilators are fitted with an internal baffle which rises above the lower edge of the exterior opening, the coaming height is measured to the top of the baffle.

11.6 Drainage arrangements

11.6.1 Ventilators are to be provided with suitable drainage arrangements, particularly where an internal baffle is fitted, *see* 11.5.4.

■ *Section 12*
Air and sounding pipes

12.1 General

12.1.1 Air and sounding pipes are to comply with the requirements of Pt 15, Ch 2,11.

12.1.2 The minimum wall thickness of steel and aluminium alloy air pipes in positions indicated in 12.2.1 is to be taken as:

$t_p = 0{,}03 d_p + 3{,}6$ mm with a maximum of 8,5 mm

where

t_p = wall thickness of air pipe, in mm

d_p = external diameter of air pipe, in mm.

12.1.3 The pipe material is to be compatible with the craft construction material.

12.1.4 Composite pipes may be acceptable for use on composite craft and will be specially considered.

12.1.5 Striking plates of suitable thickness, or their equivalent, are to be fitted under all sounding pipes.

12.1.6 For the requirements for yachts, *see also* Part 4.

12.2 Height of air pipes

12.2.1 The height of air pipes from the upper surface of decks exposed to the weather, to the point where water may have access below is normally to be not less than:

- 450 mm on the freeboard deck;
- 300 mm on the superstructure deck;

these heights being measured above deck sheathing, where fitted.

12.2.2 Lower heights may be approved in cases where these are essential for the working of the craft, provided that the design and arrangements are otherwise satisfactory.

12.2.3 An increase in the height of air pipes may be required or recommended by individual Administrations when air pipes to fuel oil and settling tanks are situated in positions where sea water could be temporarily entrapped, e.g. in recesses in the sides and ends of superstructures or deckhouses, between hatch ends, behind high sections of bulwark, etc. This may entail an increase in tank scantlings and will be specially considered.

12.2.4 Air pipes are generally to be led to an exposed deck. Alternatively, air pipes from cofferdams or void spaces may terminate in the enclosed 'tween deck space on main vehicle decks, provided the space is adequately ventilated and the air pipes are provided with weathertight closing appliances.

12.2.5 Where air pipes are led through the side of superstructures, the opening is to be at least 2,3 m above the summer load waterline.

12.3 Closing appliances

12.3.1 All openings of air and sounding pipes are to be provided with permanently attached, satisfactory means of closing to prevent the free entry of water.

12.3.2 Exposed air pipes in positions 1 and 2 are to be provided with approved automatic closing appliances.

■ *Section 13*
Particular requirements for multi-hull craft

13.1 General

13.1.1 In addition to the general requirements given in this Chapter, this Section gives particular requirements for multi-hull craft.

13.2 Multi-hull craft escape hatches

13.2.1 Multi-hull craft are to be provided with a suitable means of escape from each accommodation compartment between watertight bulkheads in the event of inversion of the craft.

13.2.2 Where the requirement given in 13.2.1 is achieved by means of escape hatches in the hull, these are to be fitted in the inboard side of each hull, or in the transom, with the lowest side of the opening at a minimum of 600 mm above the waterline in both the upright and inverted conditions of the craft. Hatch openings are to be a minimum of 450 mm x 450 mm and a maximum of 600 mm x 600 mm.

13.2.3 Escape hatch frames and covers may be of steel, aluminium alloy or FRP construction and are to be of equivalent strength to the unpierced hull side or transom in which they are fitted.

13.2.4 Hatch covers are to be weathertight when closed and the means of securing the hatch cover are to be such that weathertightness can be maintained in any sea condition.

13.2.5 Hydrostatic pressure tests are to be carried out to confirm that the proposed construction, when fitted in the hull, is able to withstand a pressure of four times the design pressure and remain watertight.

13.2.6 Hatch covers are to be flush with the hull and substantially hinged. Where fitted in the inboard side of the hull, the hinges are to be on the forward side.

13.2.7 Escape hatches are to be capable of being opened from both sides. Handles on the outside are to be suitably protected from damage or inadvertent opening.

13.3 Portlights

13.3.1 Where it is proposed to fit portlights in the hulls of wave-piercing and other non-conventional multi-hull craft, the arrangements will be specially considered.

■ *Section 1* General

1.1 Application

1.1.1 The anchoring equipment specified in this Section is suitable only for use in reasonably sheltered conditions or in emergencies. If the equipment is intended to be used during operations in the open sea, or if the sea or weather conditions in the service area are subject to unusual hazards, e.g. typhoons, etc., the equipment will be specially considered in each case.

1.1.2 Where the Equipment Number exceeds 1140 the equipment is to be in accordance with Pt 3, Ch 13 of the Rules for Ships.

1.2 Definitions

1.2.1 The definitions for use throughout this Chapter are as indicated in the appropriate Section.

1.3 Symbols

1.3.1 The following symbols are used in this Chapter, unless otherwise stated:

b_i = mean breadth of deckhouse or superstructure tier, in metres

h_i = mean height of deckhouse or superstructure tier, in metres

A = area, in m^2, in profile view of the hull, superstructure and deckhouses above the design waterline. Deckhouses with breadth less than $B/4$ are to be ignored

B_o = the greatest moulded breadth, in metres, or for craft of composite construction, the extreme breadth excluding rubbing strakes or other projections

B_1 = the greatest breadth of the outer hulls of a multi-hull craft, in metres. It is to be measured between the points of intersection of the extension of the hull sides to the normal line of the wet deck

B_2 = the greatest breadth of the centre hull in trimaran type craft, in metres. It is to be measured between the points of intersection of the extension of the hull sides to the normal line of the wet deck

D_h = the sum of b_i h_i cos θ_i for all deckhouses and superstructures tiers

G_A = air gap, as defined in Pt 5, Ch 1

α_1 = for **multi-hull** craft is the distance in metres, from the underside of the cross-deck structure to the underside of the first tier of deckhouse or superstructure
for **mono-hull** craft is the distance in metres, from the waterline to the underside of the first tier of deckhouse or superstructure

θ_i = angle of inclination aft, of tier of deckhouse front, with a line perpendicular to the static load waterline

Δ = loaded displacement, in tonnes.

1.4 Character of classification

1.4.1 To entitle a craft to the figure **1** in its character of classification, equipment in accordance with the requirements of this Chapter is to be provided. The regulations governing assignment of the character figure **1** for equipment are given in Pt 1, Ch 2,3.

1.4.2 For craft intended to be operated only in suitable areas or conditions which have been agreed by the Committee, as defined in Pt 1, Ch 2,3.5, equipment differing from these requirements may be approved if considered suitable for the particular service on which the craft is to be engaged.

1.4.3 Where the Committee has agreed that anchoring and mooring equipment need not be fitted in view of the particular service of the ship, the character letter **N** will be assigned, *see also* Pt 1, Ch 2,3.2.2.

1.4.4 Where the ship is intended to perform its primary designed service function only while it is anchored, moored, towed or linked, the character letter **T** will be assigned, *see also* Pt 1, Ch 2,3.2.2.

1.4.5 For classification purposes the character figure **1**, or either of the character letters **N** or **T**, are to be assigned.

■ *Section 2* Equipment Number

2.1 Equipment Number

2.1.1 The anchoring and mooring equipment is based on an Equipment Number, *EN*, which is to be calculated as given in 2.1.2 to 2.1.4.

2.1.2 **Mono-hull craft**

$EN = \Delta^{2/3} + 2\,(D_h + B_o\,\alpha_1) + 0{,}1A$

2.1.3 **Catamaran, Swath, SES and other twin hull craft**

$EN = \Delta^{2/3} + 2\,(D_h + B_o\,\alpha_1 + 2G_a\,B_1) + 0{,}1A$

2.1.4 **Trimarans**

$EN = \Delta^{2/3} + 2\,(D_h + B_o\,\alpha_1 + G_a\,(2B_1 + B_2)) + 0{,}1A$

2.2 Novel craft

2.2.1 Where a craft is of unusual form and proportions the requirement for equipment will be individually considered on the basis of the Rules.

■ *Section 3* Service group factors

3.1 General

3.1.1 The masses of anchors and the diameters and lengths of chain cable required by Table 5.5.1 and Table 5.6.1 respectively are for craft in **Service Group G4**.

3.2 G1 craft

3.2.1 For craft in **Service Group G1**, the equipment is generally to be that required for craft in **Service Group G2**; proposals for further reductions will be specially considered.

3.3 G2, G3 and G4 craft

3.3.1 For craft in **Service Groups G2**, **G3**, and **G4**, the mass of the anchor required by Table 5.5.1 may be multiplied by the following factors:

Service Group G2	0,60
Service Group G3	0,73
Service Group G4	1,00

3.3.2 The length and diameter of chain cable are to be those required by Table 5.6.1 corresponding to the reduced anchor mass given in Table 5.5.1.

3.3.3 Towlines and mooring lines are to be those required by Table 5.7.1 corresponding to the equipment number as determined from Section 2.

3.3.4 For service craft on particular duties, a further reduction in the mass of the anchor may be given in accordance with Section 4.

3.4 G5 craft

3.4.1 Craft in **Service Group G5** are considered for the purposes of this Chapter to be unrestricted in their service, and the equipment is to be in accordance with Pt 3, Ch 13 of the Rules for Ships.

3.5 G6 craft

3.5.1 **Service Group G6** covers yachts and patrol craft having unrestricted service.

3.5.2 For yachts, the mass of the anchors required by Table 5.5.1 may be multiplied by the craft type factor indicated in Section 4. The length and diameter of chain cable are to be those required by Table 5.6.1 corresponding to the reduced anchor mass given in Section 4.

3.5.3 For patrol craft, the equipment is to be in accordance with Pt 3, Ch 13 of the Rules for Ships for unrestricted service.

■ *Section 4* Craft type factors

4.1 General

4.1.1 The mass of the anchors required by Table 5.5.1 and corrected for service group factors in accordance with Section 3 (where applicable), are to be corrected by the craft type factors indicated in this Section.

4.2 Craft type factors

4.2.1 **Yachts** with an Equipment Numeral, *EN*, of less than or equal to 220 as determined in 2.1, may have the mass of the anchors as required by Table 5.5.1 reduced by the craft type factor, k_y, in accordance with the following:

$$k_y = \frac{EN}{500} + 0{,}56$$

4.2.2 For yachts with an Equipment Numeral, *EN*, in excess of 220, the craft type factor, k_y, is to be taken as unity.

4.2.3 **Pilot and Patrol** craft operating within **Service Group G1**, and which do not normally anchor in the course of their duties, with an Equipment Numeral *EN* of less than or equal to 220 as determined in 2.1, may have the mass of the anchor as required by Section 3 reduced by the craft type factor, k_{p1}, in accordance with the following:

$$k_{p1} = \frac{EN}{980} + 0{,}28$$

4.2.4 **Pilot and patrol** craft operating within **Service Group G2**, and which do not normally anchor in the course of their duties, with an Equipment Numeral *EN* of less than or equal to 100 as determined in 2.1.2, may have the mass of the anchor as required by Section 3 reduced by the craft type factor, k_{p2}, in accordance with Table 5.4.1.

Table 5.4.1 Craft type factor

Equipment Numeral, *EN*	Craft type factor, k_{p2}
≥ 5 ≤ 40	0,8
> 40 ≤ 100	0,9
> 100	1,0

■ *Section 5* Anchors

5.1 General

5.1.1 The Rules are based on the use of high holding power (HHP) type anchors.

5.1.2 When ordinary holding power anchors are used as bower anchors, the mass given in Table 5.5.1 is to be increased by 33 per cent.

5.1.3 Where it is proposed to fit other types of anchor, the mass will be specially considered.

5.1.4 Craft other than yachts are to be provided with a single anchor on board which must be ready for immediate use.

5.1.5 In addition, the craft is to be supplied with one spare anchor located at each of the ports on its regular scheduled service, or alternatively the spare anchor may be carried on board.

5.1.6 **Yachts** are to be provided with two anchors on board. Each anchor must have the rule length of chain cable attached. Only one anchor is required to be ready for immediate deployment, i.e. around the capstan. The masses of anchors may be of the following combinations:

(a) The mass of the first anchor is to be not less than 100 per cent of the Rule value for the type of anchor concerned. The mass of the second anchor is to be not less than 70 per cent of the Rule value for the type concerned.

(b) The mass of each anchor is to be not less than 90 per cent of the Rule value for the type of anchor concerned.

5.1.7 The fitting of a single anchor on board yachts will be specially considered. The mass of the single anchor is to be not less than 100 per cent of the Rule value for the type of anchor concerned.

Table 5.5.1 Anchors

Equipment number		High holding power bower anchors	
Exceeding	Not exceeding	Number of anchors	Mass of anchor, in kg
—	5	1	11
5	10	1	13
10	15	1	17
15	20	1	22
20	25	1	27
25	30	1	32
30	35	1	37
35	40	1	44
40	45	1	52
45	50	1	59
50	70	1	80
70	90	1	117
90	110	1	154
110	130	1	197
130	150	1	240
150	175	1	292
175	205	1	360
205	240	1	428
240	280	1	495
280	320	1	585
320	360	1	675
360	400	1	765
400	450	1	855
450	500	1	968
500	550	1	1080
550	600	1	1193
600	660	1	1305
660	720	1	1440
720	780	1	1575
780	840	1	1710
840	910	1	1845
910	980	1	1980
980	1060	1	2138
1060	1140	1	2295

5.1.8 Anchors which must be specially laid the right way up, or which require the fluke angle or profile to be adjusted for varying types of sea bed, will not generally be approved for normal craft use. In such cases suitable tests may be required.

5.1.9 Anchors are to be of an approved design. The design of all anchor heads is to be such as to minimise stress concentrations, and in particular, the radii on all parts of cast anchor heads are to be as large as possible, especially where there is considerable change of section.

5.2 Materials

5.2.1 The requirements for anchor materials are contained in the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

5.2.2 Anchors made of stainless steels or aluminium alloy may be acceptable subject to special consideration.

5.2.3 Where aluminium alloy anchors are proposed, due consideration is to be given to the compatibility of such anchors with the materials of the chain cable, anchor shackle, etc., in order to avoid galvanic corrosion.

5.3 Testing

5.3.1 Testing of anchors is to be carried out in accordance with Chapter 10 of the Rules for Materials.

5.3.2 For holding power testing requirements relating to high holding power anchors, *see* Ch 10,1.7 of the Rules for Materials.

5.4 Anchor shackle

5.4.1 Steel anchor shackles are to be forged or cast steel of approved manufacturer.

5.5 Anchor stowage

5.5.1 Anchors are generally to be housed in suitable hawse pipes, or stowed in dedicated chocks on deck.

5.5.2 Hawse pipes and anchor pockets are to be in accordance with 9.3. Alternatively, roller fairleads of suitable design may be fitted. Where hawse pipes are not fitted, alternative arrangements will be specially considered.

5.6 Super high holding power (SHHP) type anchors

5.6.1 Proposals to use anchors of the SHHP type will be subject to special consideration.

5.6.2 Final acceptance will be dependent upon satisfactory strength and performance tests.

5.6.3 Anchors of designs for which approval is sought as super high holding power anchors are to be tested at sea to show that they have holding powers of at least four times those of approved standard stockless anchors of the same mass.

5.7 Tolerances

5.7.1 The mass of each high holding power anchor given in Table 5.5.1 is for anchors of equal mass. The masses of individual anchors may vary by ±7 per cent of the masses given in the Table, provided that the total mass of the anchors is not less than would have been required for anchors of equal mass.

5.8 Identification

5.8.1 Identification of anchors which have been tested is to be in accordance with Ch 10,1.4 of the Rules for Materials.

■ *Section 6* Anchor cable

6.1 General

6.1.1 Anchor cable may be of stud link chain, short link chain, wire rope or fibre rope, subject to the requirements of this Section.

6.1.2 For each anchor required to be carried on board, *see* 5.1.6, a length of anchor cable, as indicated in Table 5.6.1, is to be provided.

6.2 Chain cable

6.2.1 The diameter of stud link chain cable is to be as indicated in Table 5.6.1.

6.2.2 Short link chain cable may be accepted provided that the breaking load is not less than that of stud link chain cable of the diameter required by Table 5.6.1.

6.2.3 Chain cables may be of mild steel, special quality steel or extra quality steel in accordance with the requirements of Ch 10 of the the Rules for Materials, and are to be graded in accordance with Table 5.6.2.

6.2.4 Grade U1 material having a tensile strength of less than 400 N/mm^2 is not to be used in association with high holding power anchors. Grade U3 material is to be used only for chain 20,5 mm or more in diameter.

6.2.5 In addition to 6.2.3 special consideration will be given to the use of chain cable of stainless steel. Stainless steel is to be of a suitable type, details of which are to be submitted for consideration.

6.2.6 The form and proportion of links and shackles are to be in accordance with Chapter 10 of the Rules for Materials.

Table 5.6.1 Chain cable

Mass of HHP bower anchor, in kg	Length of chain cable, in metres	Stud link chain cable diameter, in mm		
		Mild steel (Grade:1 or U1)	Special quality steel (Grade:U2)	Extra special quality steel (Grade:U3)
11	55	8	–	–
13	55	8	–	–
17	55	8	–	–
22	55	9	–	–
27	55	9	–	–
32	82,5	9	–	–
37	82,5	11,2	–	–
44	82,5	11,2	–	–
52	110	11,2	–	–
59	110	12,5	–	–
80	110	12,5	–	–
117	110	14	12,5	–
154	110	16	14	–
197	137,5	17,5	16	–
240	137,5	19	17,5	–
292	137,5	20,5	17,5	–
360	137,5	22	19	–
428	165	24	20,5	–
495	165	26	22	20,5
585	165	28	24	22
675	192,5	30	26	24
765	192,5	32	28	24
855	192,5	34	30	26
968	192,5	36	32	28
1080	220	38	34	30
1193	220	40	34	30
1305	220	42	36	32
1440	220	44	38	34
1575	220	46	40	36
1710	247,5	48	42	36
1845	247,5	50	44	38
1980	247,5	52	46	40
2138	247,5	54	48	42
2295	247,5	56	50	44

Table 5.6.2 Grades of steel for use as chain cable

Grade	Material	Tensile strength (N/mm^2)
U1	Mild steel	300 – 490
U2 (a)	Special quality steel (wrought)	490 – 690
U2 (b)	Special quality steel (cast)	490 – 690
U3	Extra special quality steel	690 min

6.3 Testing

6.3.1 Chain cable with a diameter of 12,5 mm or above is to be certified by Lloyd's Register (hereinafter referred to as 'LR'). Chain cable with a diameter below 12,5 mm is to be certified by a recognised testing establishment.

6.3.2 All chain cables are to be tested at establishments and on machines recognized by the Committee and under the supervision of LR's Surveyors or other Officers recognized by the Committee, and in accordance with Chapter 10 of the Rules for Materials.

6.3.3 Test certificates showing particulars of size and weight of cable and of the test loads applied are to be furnished. These certificates are to be examined by the Surveyors when the cables are placed on board the craft.

6.4 Wire rope

6.4.1 When the Equipment Number does not exceed 500 for craft in **Service Groups G1**, **G2** and **G3**, steel wire rope may be accepted in lieu of chain cable under the following conditions:

(a) A length of chain of the diameter specified in Table 5.6.1 is to be fitted to the anchor. The total length of chain is to be not less than 10 per cent of the total required by Table 5.6.1. In no case is the length of chain attached to an anchor to be less than 9 metres.

(b) The wire rope used in lieu of chain cable is to have a breaking load of not less than that of the chain cable it replaces.

(c) The combined length of the chain cable specified in (a) and the wire is to be not less than the length of chain cable required by Table 5.6.1.

(d) Thimbles are to be fitted at both ends of the wire rope, as appropriate.

(e) Suitable precautions are to be taken to reduce the wear on the wire rope at fairleads, etc.

6.4.2 Steel wire ropes are to be manufactured, tested and certified as required by Chapter 10 of the Rules for Materials.

6.5 Fibre rope

6.5.1 When the Equipment Number does not exceed 100, polyamide (or other equivalent synthetic fibre) rope may be accepted in lieu of wire rope, subject to compliance with 6.4.1(a) to (d).

6.5.2 Fibre ropes are to be manufactured, tested and certified as required by Chapter 10 of the Rules for Materials.

6.5.3 Synthetic fibre ropes are to be ultra-violet inhibited as necessary, dependent upon their type.

6.6 Cable clench

6.6.1 Provision is to be made for securing the inboard ends of the cables to the structure. This attachment is to have a working strength of not less than 10 per cent of the breaking strength of the chain cable, and the structure to which it is attached is to be adequate for this load. Attention is drawn to the advantages of arranging that the cable may be slipped from an accessible position outside the chain cable locker. The proposed arrangement for slipping the chain cable, if constructed outside the chain locker, must be made watertight.

6.7 Cable stopping and release arrangements

6.7.1 It is recommended that suitable bow chain stoppers be provided. The scantlings of these chain stoppers are outwith the scope of the Rules, however the structure in way is to be designed with due regard to the applied loading. Support under chain stopping arrangements is to be to the satisfaction of the Surveyor.

6.8 Cable locker

6.8.1 Adequate storage is to be provided to accommodate the full length of anchor cable.

6.8.2 The chain locker is to be of a capacity and depth adequate to provide an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. Chain or spurling pipes are to be of suitable size and provided with chafing lips. The port and starboard cables are to be separated by a division in the locker.

6.8.3 Chain lockers fitted abaft the collision bulkhead are to be watertight and the space to be efficiently drained.

■ *Section 7* Mooring ropes and towlines

7.1 Mooring ropes

7.1.1 Craft under 90 m in length are to be equipped with mooring ropes in accordance with Table 5.7.1.

7.1.2 The lengths of individual mooring lines in Table 5.7.1 may be reduced by up to seven per cent of the Table length, provided that the total length of mooring lines is not less than would have resulted had all lines been of equal length. Proposals to fit individual mooring lines of reduced length to suit the particular service will be specially considered.

7.2 Materials

7.2.1 Mooring lines may be of steel wire rope, natural fibre or synthetic fibre. The diameter, construction and specification of wire or natural fibre mooring lines are to comply with the requirements of Chapter 10 of the Rules for Materials. Where it is proposed to use synthetic fibre ropes, the size and construction will be specially considered.

7.3 Testing and certification

7.3.1 Mooring ropes are to be tested and certified in accordance with Chapter 10 of the Rules for Materials.

7.4 Towlines

7.4.1 Towlines are not required for classification other than for craft which are required to comply with the *IMO Code of Safety for High Speed Craft.* The details given in Table 5.7.1 are for guidance purposes only.

7.5 Bollards, fairleads and bull rings

7.5.1 Means are to provided to enable mooring lines to be adequately secured on board the craft. It is recommended that the total number of suitably placed bollards on either side of the craft and/or the total brake holding power of mooring winches should be capable of holding not less than 1,5 times the sum of the maximum breaking strengths of the mooring lines required or recommended. Attention is drawn to the existence of a number of National Standards for bollards and fairleads, and to the importance of ensuring that their seating arrangements, including the supporting hull structure, are efficiently constructed and adequate for the intended loads.

7.6 Towing requirements

7.6.1 Craft which are to comply with the *IMO Code of Safety for High Speed Craft* are to be provided with adequate arrangements to enable the craft to be towed in the worst intended environmental conditions. It is recommended that other craft comply with this requirement.

7.7 Towing bitts

7.7.1 Where towage is to be from more than one point a suitable bridle is to be provided.

7.7.2 Details of the structural scantlings, arrangements, loadings and design assumptions for the towing bitts are to be submitted for consideration.

7.7.3 The towing arrangements should be such that damage to the towline or bridle from abrasion is minimised.

Table 5.7.1 Towlines and mooring lines

Equipment Number		Towline (*See* Notes)		Mooring lines		
Exceeding	Not exceeding	Minimum length, in metres	Minimum breaking strength, in kN	Number of lines	Minimum length of each line, in metres	Minimum breaking strength, in kN
–	5	90	19,9	2	55	13,9
5	10	90	22,5	2	55	17,6
10	15	90	27,7	2	55	21,5
15	20	90	32,9	2	55	24,5
20	25	110	38,1	2	55	26,6
25	30	110	43,3	2	55	28,2
30	35	110	48,5	2	55	29,6
35	40	135	53,7	2	55	30,8
40	45	135	58,9	2	70	31,8
45	50	135	64,1	2	85	32,7
50	70	180	71,0	2	100	35,5
70	90	180	82,1	2	100	39,3
90	110	180	93,2	2	110	43,1
110	130	180	104,3	2	110	46,6
130	150	180	115,3	2	120	50,2
150	175	180	127,8	2	120	54,4
175	205	180	143,0	2	120	58,8
205	240	180	161,1	2	120	64,2
240	280	180	181,8	3	120	71,1
280	320	180	204,0	3	140	78,5
320	360	180	226,1	3	140	85,8
360	400	180	248,3	3	140	93,2
400	450	180	273,2	3	140	100,5
450	500	180	300,9	3	140	107,9
500	550	180	328,6	4	160	112,8
550	600	180	356,3	4	160	117,7
600	660	180	386,8	4	160	122,6
660	720	180	420,1	4	160	127,5
720	780	180	453,3	4	170	132,4
780	840	180	486,5	4	170	137,3
840	910	180	522,5	4	170	142,2
910	980	180	561,3	4	170	147,1
980	1060	180	602,9	4	180	156,9
1060	1140	180	647,2	4	180	166,7

NOTES
1. Towline specified for guidance only, *see* 7.4.1.
2. Wire ropes used for towlines and mooring lines are generally to be of a flexible construction with not less than:
   144 wires in six strands with seven fibre cores for strengths up to 490 kN
   222 wires in six strands with one fibre core for strengths exceeding 490 kN
   The wires to be laid around the fibre centre of each strand are to be up in not less than two layers.
3. Wire ropes for towlines and mooring lines used in association with mooring winches (on which the rope is stored on the winch drum) are to be of suitable construction.
4. Irrespective of strength of requirements, no fibre rope is to be less than 12 mm diameter.

7.8 Mooring winches

7.8.1 Mooring winches where provided are to be suitable for the intended purpose. Supports under the winches are to be to the Surveyor's satisfaction.

7.8.2 Mooring winches are to be fitted with drum brakes, the strength of which is sufficient to prevent unreeling of the mooring line when the rope tension is equal to 80 per cent of the breaking strength of the rope as fitted on the first layer on the winch drum, *see also* 7.5.1.

Section 8
Windlass design and testing

8.1 General

8.1.1 A windlass, capstan or winch of sufficient power and suitable for the size of anchor cable is to be fitted to the craft. Where Owners require equipment significantly in excess of Rule requirements, it is their responsibility to specify increased windlass power.

8.1.2 Windlasses may be hand or power operated, subject to the requirements of 8.2.3.

8.1.3 Where steel wire rope is used in lieu of chain cable, a suitable winch with sufficient drum capacity to store the length of wire rope fitted is to be provided.

8.1.4 The windlass, anchoring capstans and winches are to be of types approved by LR.

8.1.5 On craft equipped with anchors having a mass of over 50 kg windlass(es) of sufficient power and suitable for the type and size of chain cable are to be fitted. Arrangements with anchor davits will be specially considered.

8.2 Performance

8.2.1 The following performance criteria are to be used as a design basis for the windlass:

(a) The windlass is to have sufficient power to exert a continuous duty pull of:
$28{,}00d_c^2$ N – for Grade U1 chain, with $d_c < 14$ mm
$36{,}79d_c^2$ N – for Grade U1 chain, with $d_c \geq 14$ mm
$41{,}68d_c^2$ N – for Grade U2 chain
$46{,}60d_c^2$ N – for Grade U3 chain
over a period of $0{,}12L_c$ minutes. The test period need not be taken longer than 30 minutes
where
d_c is the chain diameter, in mm
L_c is the total length of chain cable on board, in metres, as given by Table 5.6.1.

(b) The windlass is to have sufficient power to exert, over a period of at least two minutes, a pull equal to the greater of:
   (i) short-term pull:
   1,5 times the continuous duty pull as defined in 8.2.1(a).
   (ii) anchor breakout pull:
   $12{,}18W_a + 7{,}0L_c\,d_c^2/100$ N
where
W_a is the mass of bower anchor(kg) as given in Table 5.5.1.

(c) In the absence of a chain stopper, the windlass, with its braking system in action and in conditions simulating those likely to occur in service, is to be able to withstand, without permanent deformation or brake slip, a load, applied to the cable, given by:
$K_b\,d_c^2\,(44 - 0{,}08d_c)$ N
where
K_b = 7,85 for Cable Grade U1
= 11,00 for Cable Grade U2
= 15,70 for Cable Grade U3.

(d) Where a chain stopper is fitted, the windlass braking system is to have sufficient brake capacity to ensure safe stopping when paying out the anchor and chain. It is the Master's responsibility to ensure that the chain stopper is in use when riding at anchor. At clearly visible locations on the bridge and adjacent to the windlass control position, the following notice is to be displayed adjacent to the windlass control position, and at clearly visible locations on the bridge if the windlass can be operated remotely:
'The brake is rated to permit controlled descent of the anchor and chain only. The chain stopper is to be used at all times whilst riding at anchor.'
The performance criteria are to be verified by means of shop tests in the case of windlasses manufactured on an individual basis. Windlasses manufactured under LR's Type Approval Scheme for Marine Engineering Equipment will not require shop testing on an individual basis.

8.2.2 Windlass performance characteristics specified in 8.2.1 and 8.3.2 are based on the following assumptions:

(a) one cable lifter only is connected to the drive shaft,
(b) continuous duty and short term pulls are measured at the cable lifter,
(c) brake tests are carried out with the brakes fully applied and the cable lifter declutched,
(d) the probability of declutching a cable lifter from the motor with its brake in the off position is minimized,
(e) hawse pipe efficiency assumed to be 70 per cent.

8.2.3 Hand-operated winches are only acceptable if the effort required at the handle does not exceed 15 kgf for raising one anchor at a speed of not less than 2 m/min and making about thirty turns of the handle per minute.

8.2.4 Winches suitable for operation by hand as well as by external power are to be so constructed that the power drive cannot activate the hand drive.

8.3 Tests and trials

8.3.1 Where shop testing is not possible and Type Approval has not been obtained, calculations demonstrating compliance with 8.2.1 are to be submitted together with detailed plans and an arrangement plan showing the following components:

- Shafting.
- Gearing.
- Brakes.
- Clutches.

8.3.2 During trials on board the craft the windlass should be shown to be capable of raising the anchor from a depth of 82,5 m to a depth of 27,5 m at a mean speed of 9 m/min. Where the depth of water in the trial area is inadequate, or the anchor cable is less than 82,5 m, suitable equivalent simulating conditions will be considered as an alternative.

8.4 Seatings

8.4.1 The windlass is to be efficiently bedded and secured to the deck. The thickness of the deck in way of the windlass is to be increased, and adequate stiffening is to be provided, to the Surveyor's satisfaction. The structural design integrity of the bedplate is the responsibility of the Builder and windlass manufacturer.

■ *Section 9* Structural details

9.1 General

9.1.1 An easy lead of the cables from the windlass to the anchors and chain lockers is to be arranged. Where cables pass over or through stoppers, these stoppers are to be manufactured from ductile material and be designed to minimise the probability of damage to, or snagging of, the cable. They are to be capable of withstanding without permanent deformation a load equal to 80 per cent of the Rule breaking load of the cable passing over them.

9.2 Bulbous bow and wave piercing bow arrangements

9.2.1 The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness is to be the same as that required for plated stems by Parts 6, 7 and 8 of the Rules for steel, aluminium alloy and composite materials respectively.

9.3 Hawse pipes and anchor recesses

9.3.1 Hawse pipes, bow rollers and other deck gear, of adequate size and construction, are to be provided for handling and securing the anchors and are to be efficiently attached to the structure and arranged to give an easy lead to the cable.

9.3.2 The hawse pipes are to be of sufficient size and thickness, and arranged to give an easy lead for the cable to the windlass.

9.3.3 Hawse pipes and anchor pockets are to be of ample thickness and of a suitable size and form to house the anchors efficiently, preventing, as much as practicable, slackening of the cable or movements of the anchor being caused by wave action. The shell plating and framing in way of the hawse pipes are to be reinforced as necessary, *see* 9.5.1. Substantial chafing lips are to be provided at shell and deck. These are to have sufficiently large, radiused faces to minimise the probability of cable links being subjected to high bending stresses. Alternatively, roller fairleads of suitable design may be fitted. Where unpocketed rollers are used, it is recommended that the roller diameter be not less than eleven times the chain diameter. Where hawse pipes are not fitted, alternative arrangements will be specially considered.

9.4 Spurling pipes

9.4.1 Satisfactory means are to be provided to prevent inadvertent flooding of chain lockers. It is recommended that steel plates in halves, hooked over the spurling pipe tops, be provided on top of which cement may be laid before lashing a canvas cover. Suitable alternatives will be considered.

9.4.2 The design of the windlass is to be such that the following requirements or equivalent arrangements will minimise the probability of the chain locker or forecastle being flooded in bad weather:

(a) a weathertight connection can be made between the windlass bedplate, or its equivalent, and the upper end of the chain pipe, and

(b) access to the chain pipe is adequate to permit the fitting of a cover or seal, of sufficient strength and proper design, over the chain pipe while the craft is at sea.

9.5 Local reinforcement

9.5.1 The thickness of shell plating determined in accordance with the Rule requirements is to be increased locally by not less than 50 per cent in way of hawse pipes.

9.5.2 Supports under windlasses and winches are to be suitably reinforced.

■ *Section 1* General requirements

1.1 Scope

1.1.1 These Rules set down the criteria for the assessment of the noise and vibration on special service craft and are applied in addition to the other relevant requirements of the *Rules and Regulations for the Classification of Special Service Craft* (hereinafter referred to as the Rules for Special Service Craft).

1.1.2 For the purpose of these Rules, the term ‘ship’, unless otherwise stated, applies to Special Service Craft and Yachts.

1.1.3 Compliance with these Rules is optional.

1.1.4 These Rules provide for two alternatives:
(a) **Class Notations** which indicate that the ship has been assessed and complies with noise and vibration criteria of these Rules and that a periodic survey regime has been established for the lifetime of the ship.
(b) **Certificate of Compliance** which provides evidence that the ship has been assessed and found to comply with the noise and vibration criteria of these Rules.

1.1.5 These Rules recognize existing National and International Standards and specify levels of noise and vibration currently achievable using good engineering practice. Compliance with these requirements will be assessed by review of procedures, inspection and measurement of the relevant parameters and pre-survey reviews. Inspections and measurements are to be conducted, witnessed or assessed by Lloyd's Register's Surveyors unless otherwise agreed by Lloyd's Register (hereinafter referred to as ‘LR’).

1.1.6 Accommodation comfort is a function of ship type and layout. These Rules address two types of ship:
(a) High-speed (e.g. surface effect ships, wave piercing catamarans, hydrofoils).
(b) Yacht (e.g. sailing yachts, motorised pleasure craft).

1.1.7 These Rules include levels of noise and vibration which should be verified by measurements following completion of the ship. It is recommended that the Builders undertake calculations of noise and vibration characteristics so that any potential problem areas can be identified and control measures implemented.

1.1.8 The sound pressure levels for audible alarms and public address systems fitted in accordance with other Sections of the Rules are to satisfy IMO Resolution A.830(19), Code on Alarms and Indicators.

1.2 Definitions

1.2.1 **Passenger spaces** are defined as all areas intended for passenger use, and include the following:
(a) Passenger cabins.
(b) Public spaces (e.g. restaurants, hospitals, lounges, reading and games rooms, gymnasiums, corridors and/or shops).
(c) Open deck recreation areas.

1.2.2 **Crew spaces** are defined as all areas intended for crew use only, and include the following:
(a) Accommodation spaces (e.g. cabins, offices, mess rooms, recreation rooms).
(b) Work spaces.
(c) Navigation spaces.

1.2.3 **Noise level** is defined as the A-weighted sound pressure level measured in accordance with ISO 2923.

1.2.4 **Vibration level** is defined by the application of either of the two versions of the ISO 6954 standard:
(a) Where ISO 6954:1984 is applied, the vibration level is defined as the single amplitude peak value of deck structure vibration during a period of steady state vibration, representative of maximum repetitive behaviour, in mm/s, over the frequency range 5 to 100 Hz. For frequencies below 5 Hz, the requirements for vibration levels follow constant acceleration curves corresponding to the acceleration at 5 Hz.
(b) Where ISO 6954:2000 is applied, the vibration level is defined as the overall frequency weighted r.m.s. value of vibration during a period of steady-state operation over the frequency range 1 to 80 Hz.

In general, ISO 6954-2000 is the preferred standard to be applied, however ISO 6954-1984 may be applied where there are practical difficulties in the application of ISO 6954-2000 and this has been agreed between the Owner and Builder.

1.3 Class notations

1.3.1 The class notations described in 1.3.2 to 1.3.6 provide standards for noise and vibration levels in different spaces at the time of delivery and during the ship’s life if substantial changes to the machinery installation or interior arrangements are made.

1.3.2 The **PAC** (Passenger Accommodation Comfort), **CAC** (Crew Accommodation Comfort) and **PCAC** (Passenger and Crew Accommodation Comfort) notations are optional and are primarily intended to apply to passenger ships. If requested, however, any ship can be assessed for compliance, using these requirements as the basis for the assessment and a LR Certificate of Compliance issued (*see* 1.1.4(b) and 1.4).

1.3.3 The **PAC** notation indicates that the passenger accommodation meets the acceptance criteria whilst the **CAC** notation indicates that the crew accommodation and work areas meet the acceptance criteria. The **PCAC** notation indicates that the passenger and crew spaces both meet the acceptance criteria.

1.3.4 For ships which achieve the noise and vibration comfort standards specified in these Rules, the notation **PAC**, **CAC** or **PCAC** will be assigned.

1.3.5 Following the **PAC** or **CAC** notation, numerals **1**, **2** or **3** will indicate the acceptance criteria to which the noise and vibration levels have been assessed. In the case of the **PCAC** notation, two numerals will be assigned. The first will indicate the acceptance criteria for passenger accommodation, whilst the second will indicate the crew comfort criteria.

1.3.6 For particular vessels, impact insulation and transient noise in accordance with 2.5 and 2.6 together with any additional or more stringent noise and vibration criteria may be assessed within the scope of the notations where agreed between the Owner, Builder and LR.

1.4 Certificate of Compliance

1.4.1 A Certificate of Compliance records that a ship has been designed and constructed to satisfy the noise and vibration criteria contained in these Rules. This is to be confirmed by measurements and reporting in accordance with Sections 4 and 5.

1.4.2 A Certificate of Compliance is optional and if requested, any ship can be assessed for compliance using the Rule requirements.

1.4.3 Where noise and vibration levels are at variance with those prescribed by these Rules, they will be added to the certificate for information purposes.

1.4.4 A Certificate of Compliance will be issued after the initial survey required by Section 6.

■ *Section 2*
Noise

2.1 Assessment criteria

2.1.1 Where a space is occupied by both passengers and crew, the more stringent of the relevant requirements apply unless agreed between the Builder and Owner and advised to LR.

2.2 Passenger accommodation and public spaces

2.2.1 Under test conditions specified in 4.2, the applicable noise levels specified in Tables 6.2.1 and 6.2.2 should not generally be exceeded. *See* 2.2.3.

Table 6.2.1 High speed craft – Maximum noise levels in dB(A)

Location		Acceptance Numeral		
		1	2	3
Public spaces:	Excluding shops	60	65	70
	Shops	65	68	72

Table 6.2.2 Yachts – Maximum noise levels in dB(A)

Location		Acceptance Numeral		
		1	2	3
Passenger cabins:	Standard	53	55	58
	Superior	50	53	55
Lounges		55	58	60
Open deck recreation areas:	2nd deck from WL	72	75	79
	3rd deck from WL	63	66	70
Wheelhouse		60	62	75

NOTES
1. The levels may be exceeded by 5dB(A) within 3 m of a ventilation inlet/outlet or machinery intake/uptake on open decks.
2. The levels may be exceeded by 3dB(A) in accommodation above the propellers for three decks above the mooring deck.
3. The levels for open deck recreation areas refer to ship generated noise only. On open deck spaces the noise generated from the effects of wind and waves can be considered separately to limits agreed between the Builder and Owner and advised to LR for the trial conditions.

2.2.2 For cabins bordering discotheques and similar entertainment areas, the deck and bulkhead sound insulation is to be sufficient to ensure that the maximum cabin noise levels are not exceeded even when high external noise levels prevail.

2.2.3 Acceptance of noise levels greater than those specified in Tables 6.2.1 and 6.2.2 may be considered where agreed between the Owner and Builder. Not more than 20 per cent of the passenger cabins, 30 per cent of the public spaces and 20 per cent of the crew cabins should exceed the relevant noise criteria by more than 3 dB(A).

2.2.4 Acoustic insulation of bulkheads and decks between passenger spaces is to be generally in accordance with the values of the weighted apparent sound reduction index, R_w, as given in Table 6.2.3, calculated using ISO 717/1. *See also* 2.2.6.

Table 6.2.3 Minimum air-borne sound insulation indices, R_w

Location		Acceptance Numeral		
		1	2	3
Passenger cabins:	Standard	40	38	37
	Superior	45	42	40
Cabin to corridor:	Standard	38	36	34
	Superior	42	40	37
Cabin to stairway:	Standard	47	45	43
	Superior	50	47	45
Cabin to public space (excluding corridoors/ stairwells and discotheques):	Standard	52	48	48
	Superior	55	50	50
Discotheques to cabins		60	60	60
Discotheques to stairwells and public spaces		52	52	52
Cabin to machinery rooms and engine casing		55	53	50

2.2.5 For the purpose of selecting acoustic sound insulation, the following sound noise levels may be used with the agreement of the Owner and Builder:

(a) Cabins – 80 dB(A).
(b) Dining Rooms – 85 dB(A).
(c) Corridors – 90 dB(A).
(d) Discotheques, Theatres, Entertainment Areas – 105 dB(A).

2.2.6 Acceptance of bulkhead and deck acoustic insulation values less than those specified in Table 6.2.3 may be considered where agreed between the Owner and Builder. Not more than 20 per cent of the interfaces tested should have airborne sound insulation indices, R_w, more than 3 dB(A) lower than the minimum specified values.

2.3 Crew accommodation and work areas

2.3.1 Under the applicable test conditions specified in 4.2, the noise levels specified in Tables 6.2.4 and 6.2.5 are not to be exceeded.

2.3.2 Crew space insulation is to comply with the requirements of IMO Resolution A.468(XII).

Table 6.2.4 Crew accommodation – Maximum noise levels in dB(A)

Location		Acceptance Numeral		
		1	2	3
Sleeping cabins, hospitals		52	55	60
Day cabins		55	60	60
Office conference rooms		55	60	65
Mess rooms, lounges, reception areas:	Within accommodation	57	60	65
	On open decks	65	70	75
Alleyways, changing rooms, bathrooms, lockers		70	75	75

NOTE
The levels may be exceeded by 5dB(A) within 3 m of a ventilation inlet/outlet or machinery intake/uptake on open decks.

Table 6.2.5 Crew work areas – maximum noise levels in dB(A)

Location	dB(A) level
Machinery space(continuously manned) e.g. stores	90
Machinery space(not continuously manned) e.g. pump, refrigeration, thrusters or fan rooms	110
Workshops	85
Machinery control rooms	75
Wheelhouse	65
Bridge wing, additional limits: • 250 Hz band • 500 Hz band	 68 63
Radio room	60
Galleys and pantries: • Equipment not working • Individual items at 1 metre	 75 80
Normally unoccupied spaces (e.g. holds, decks)	90
Ship's whistle, on bridge or forecastle	110

2.4 Maximum noise levels

2.4.1 Where the measured noise level exceeds the specified criterion by 3 dB(A), or contains subjectively annoying low frequency or tonal components, the noise rating (NR) number is to be established in accordance with the graph shown in Fig. 6.2.1. This is achieved by plotting the linear octave band levels on the graph; the NR number is that NR curve to which the highest plotted octave band level is anywhere tangent. The specified criterion may be considered satisfied if the NR number does not exceed the specified A-weighted value minus 5 dB(A).

2.4.2 Guidance on maximum acceptable sound pressure levels and noise exposure limits for crew spaces is given in IMO Resolution A.468(XII).

2.5 Impact insulation

2.5.1 Where agreed between the Owner, Builder and LR, enhanced criteria for noise levels recognising the effects of impact sound pressures may be applied in accordance with 2.5.2 to 2.5.5.

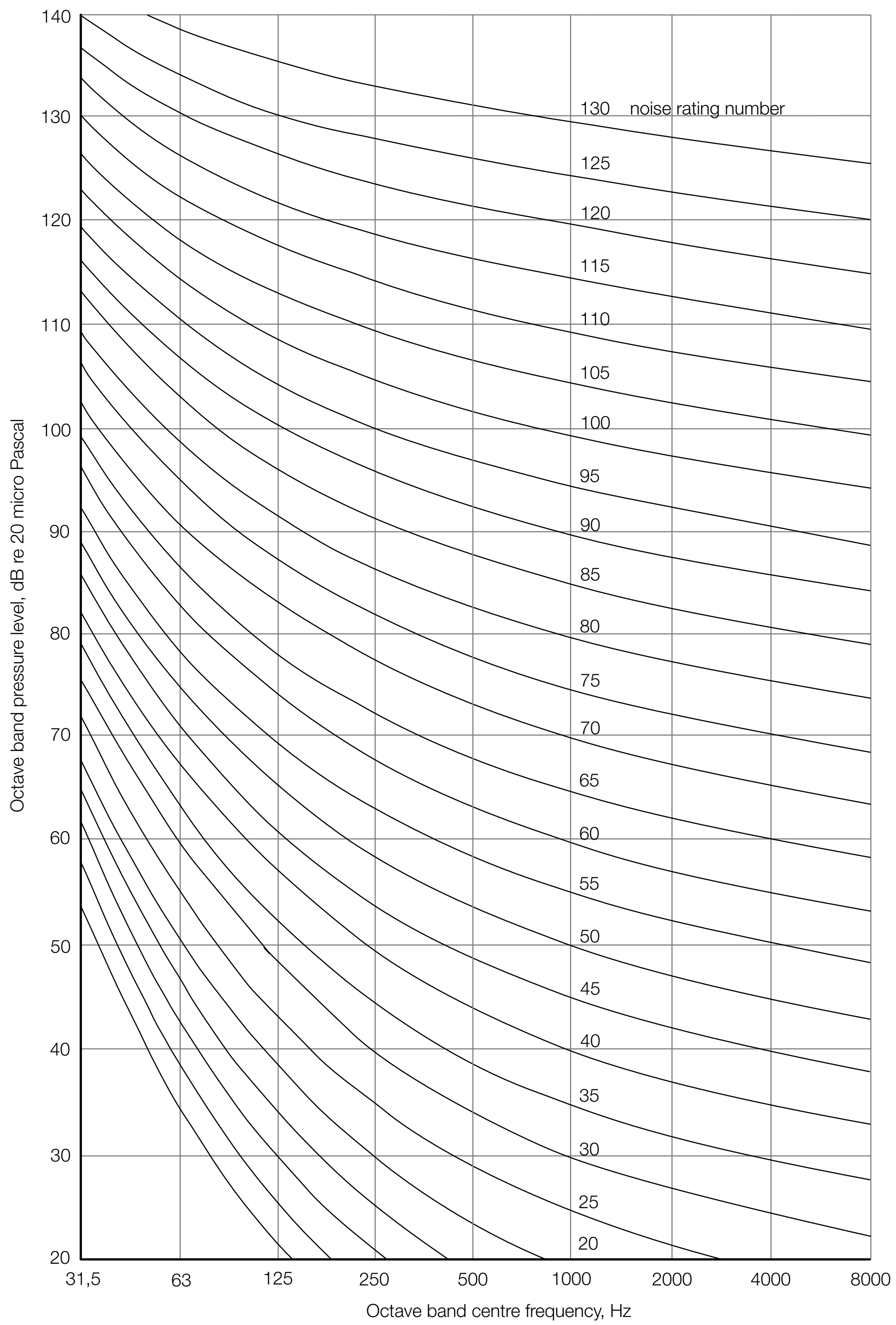


Fig. 6.2.1 Noise rating curves

2.5.2 For passenger and crew cabins located below or adjacent to dance floors, stages, aerobics and gymnasium areas, jogging tracks or other areas where impact noise is generated, the normalised impact sound pressure level measured within the cabins is not to exceed 45 dB.

2.5.3 For public rooms under dance floors, stages, aerobics and gymnasium areas, jogging tracks or other areas where impact noise is generated, the normalised impact sound pressure level within the space is not to exceed 55 dB.

2.5.4 For passenger cabins, the normalised impact sound pressure level, $L_{n,w}$, calculated using ISO 717/2, is to be generally in accordance with the values stated in Table 6.2.6. *See also 2.5.5*.

Table 6.2.6 Passenger cabins normalized impact maximum sound pressure level $L_{n,w}$

Location	dB
Below decks covered with carpet and soft materials	50
Below decks covered with hard materials (such as wood, marble or similar	60
Below dance floors, theatre or sports rooms	47

2.5.5 Acceptance of normalised impact sound pressure levels greater than those specified in Table 6.2.6 may be considered for assignment of the applicable class notation where agreed between the Owner, Builder and LR. No more than 20 per cent of the passenger cabins tested should exceed the levels specified by more than 3 dB.

2.6 Transient noise

2.6.1 Where agreed between the Owner, Builder and LR, enhanced criteria for transient noise levels may be applied in accordance with 2.6.2.

2.6.2 The maximum sound pressure level (L_{max}) emanating from any machinery or system caused by a single event that produces a noise 'spike' compared to the reference condition sound level (such as vacuum systems or valve operations) is not to cause an increase in noise in comparison with the reference condition as below:

(a) Passenger cabins and public areas: +2 dB(A)
(b) Officer cabins: +2 dB(A)
(c) Crew cabins and public areas: +3 dB(A)

A tolerance of +1 dB(*A*) may be applied to 5 per cent of cabins and public areas in each fire zone on each deck. This criterion is generally applicable to the specified maximum noise levels for the space concerned.

■ *Section 3* Vibration

3.1 Assessment criteria

3.1.1 Where a space is occupied by both passengers and crew, the more stringent of the relevant requirements apply unless agreed between the Builder and Owner and this agreement advised to LR.

3.1.2 The limits apply to vertical, fore and aft and athwartship vibrations which are to be assessed separately.

3.1.3 Under test conditions specified in 4.2, the applicable vibration levels specified in Tables 6.3.1 to 6.3.3 should not be exceeded.

Table 6.3.1 High speed craft – Maximum vibration levels

Standard:	ISO 6954:1984			ISO 6954:2000		
Units:	Peak velocity (5 –100 Hz)			Frequency weighted (1–80 Hz) velocity mm/s rms		
	Acceptance Numeral					
Location	1	2	3	1	2	3
Public spaces	2,5	4,0	5,0	2,5	3,2	3,6

Table 6.3.2 Yacht – Maximum vibration levels

Standard:	ISO 6954:1984			ISO 6954:2000		
Units:	Peak velocity (5 –100 Hz)			Frequency weighted (1–80 Hz) velocity mm/s rms		
	Acceptance Numeral					
Location	1	2	3	1	2	3
Cabins and lounges	1,0	2,0	3,0	1,8	2,0	2,5
Public spaces	1,5	3,0	4,0	2,5	2,9	3,3
Open recreation decks	2,0	3,5	4,0	2,5	3,2	3,8
NOTE The vibration level may be exceeded by 0,3 mm/s in the yacht's aft body directly above the propellers.						

3.1.4 Acceptance of vibration levels greater than those specified in Tables 6.3.1 to 6.3.3 may be considered for assignment of the applicable class notation where agreed between the Owner, Builder and LR.

Table 6.3.3 Crew spaces – Maximum vibration levels

Standard	ISO 6954:1984	ISO 6954:2000
Units	Peak velocity (5–100 Hz)	Frequency weighted (1–80 Hz) velocity mm/s rms
Location		
Accommodation and navigation spaces	5,0	3,5
Work spaces	6,0	5,0

3.1.5 The vibration levels for ISO 6954:1984 are stated as peak vibration velocity amplitude. If root mean square levels are measured, each frequency component may be converted to peak vibration velocity amplitude by application of a 1.41 multiplication factor where the ISO 6954:1984 is used for assessment against Tables 6.3.1 to 6.3.3. An approximation of maximum repetitive values may be obtained for direct comparison with the graph in ISO 6954-1984 by further application of the 1.8 conversion factor as stated in the 'Interim guidelines' note of the standard.

3.2 Passenger accommodation and public spaces

3.2.1 Passenger spaces are to comply with the overall vibration levels specified in Tables 6.3.1 and 6.3.2.

3.2.2 No more than 20 per cent of all passenger spaces/areas and public spaces should exceed the relevant vibration criteria specified in Tables 6.3.1 and 6.3.2 by more than 0,3 mm/s whether using ISO 6954:2000 or ISO 6954:1984.

3.3 Crew accommodation and work spaces

3.3.1 Crew spaces are to comply with the overall vibration levels specified in Table 6.3.3.

■ *Section 4* Testing

4.1 Measurement procedures

4.1.1 These requirements take precedence where quoted standards may differ.

4.1.2 The trial measurements may be undertaken by an approved technical organisation as defined in 4.7 or by LR. In the former case, the measurements are to be witnessed by an LR Surveyor.

4.1.3 Subject to agreement by LR and the Owner/Operator, the measurements may be undertaken by the Builder. In this case, the measurements are to be witnessed by an LR Surveyor.

4.2 Test conditions

4.2.1 Test conditions for the surveys are to be in accordance with those detailed in ISO 2923 and ISO 6954:1984 or ISO 6954:2000, as applicable.

4.2.2 The intended operating and loading conditions of the ship during assessment surveys are to be submitted to LR for agreement, prior to commencement of surveys.

4.2.3 Surveys are to be conducted when the ship is fully outfitted and all systems contributing to noise and vibration levels are operational.

4.2.4 The test conditions required for the vibration and noise measurements are to be in accordance with the following conditions:

(a) For high speed craft and yachts, prior to measurement surveys being carried out, the ship operating condition where the worst conditions are experienced between 0 and 85 per cent maximum continuous rating of the propulsion machinery is to be determined. To establish this condition, four measurement positions are to be defined with the agreement of LR and measurements taken of the parameters of interest at ship speeds corresponding to percentages of the maximum continuous rating of the propulsion machinery increasing up to 40 per cent MCR in 10 per cent intervals and from 40 per cent in 5 per cent intervals up to the 85 per cent maximum continuous rating of the propulsion machinery. If the 85 per cent maximum continuous rating condition is found to be the worst condition, then this will form the trial operating conditions. However, if a lower speed condition is found to be worse than the 85 per cent maximum continuous rating condition then both that condition and the 85 per cent maximum continuous rating condition will form the trial operating conditions. Where unavoidable, any barred range within the values required for the trial operating condition may be excluded on agreement between Owner and Builder subject to approval by LR.

(b) The power absorbed by the propeller(s) is to be that defined in 4.2.4(a). Alternatively, by special agreement, some lesser power could be accepted if it can be demonstrated by the Owner that this would correspond to a more representative normal service condition.

(c) Auxiliary machinery essential for the ship's operating conditions together with HVAC systems are to be running at their normal rated capacity during the noise and vibration trials. Combinations of auxiliary machinery operation may be necessary. In addition, the following equipment is to be running if appropriate: stabilizers, waste treatment equipment, swimming pool and jacuzzi equipment.

(d) For sea-going ships, measurements are to be taken with the ship proceeding ahead, at a constant speed and course, in a depth of water not less than five times the draught of the ship. For other ships, an appropriate water depth is to be agreed with LR prior to the trials.

(e) Trials are to be conducted in sea conditions not greater than sea state 3 on the WMO sea state code. In addition, noise measurements should not be taken when the wind force exceeds 4 on the Beaufort scale.
(f) The ship is to be at a displacement and trim representative of an operating condition.
(g) Rudder angle variations are to be limited to ±2° of the midship position and rudder movements are to be kept to a minimum throughout the measurement periods.
(h) In addition, for ships which are designed to spend a considerable period of time in harbour, the noise and vibration, are to be measured for this condition, with the auxiliary machinery and HVAC systems running at their normal rated capacity.
(j) For passenger ships, intermittently run equipment such as transverse propulsion units are to be operated at 60 per cent of their rated power for additional measurements in surrounding ship areas.

4.2.5 Prior to survey, a test programme is to be submitted for approval by LR. This programme is to contain details of the following:
(a) Measurement locations indicated on a general arrangement of the ship.
(b) The ship's loading condition during survey.
(c) The machinery operating condition, including HVAC system, during survey.
(d) Noise and vibration measuring equipment.

4.3 Noise measurements

4.3.1 Noise measurements are to be conducted in accordance with ISO 2923 and IMO Resolution A.468(XII). Measurements of noise levels are to be carried out using precision grade sound level meters conforming to IEC 60651, Type 1 or 2. Subject to demonstration, equivalent standards are acceptable.

4.3.2 Where the measured noise level exceeds the relevant criterion by 3 dB(A), or contains subjectively annoying low frequency noise or obvious tonal components, octave band readings are to be taken, with centre frequencies from 31,5 Hz to 8 kHz.

4.3.3 When outfitting is complete, and all soft furnishings are in place, sound insulation indices for passenger spaces are to be determined in accordance with ISO 140. Cabin to cabin indices are to be determined from a minimum of three locations within the passenger accommodation, the number of test locations being agreed with LR.

4.3.4 If required, impact sound measurements are to be carried out in accordance with ISO 140/7 and presented in accordance with ISO 717/2. *See* 4.4.4.

4.4 Noise measurement locations

4.4.1 Measurement locations are to be chosen so that the assessment represents the overall noise environment on board the ship. In addition to the requirements of IMO Resolution A.468(XII) for crew spaces, all public spaces and all passenger spaces are to be measured.

4.4.2 During measurement trials, recognized noise sources are to be operated at their normal level of noise output (e.g. machinery at design rating).

4.4.3 In larger sized spaces, where noise levels may vary considerably, such as restaurants, lounges, atria and open deck recreation areas, measurements are to be taken at locations not greater than 7 m apart.

4.4.4 For high speed craft having large passenger saloons, measurements are to be taken along the centreline and along both sides of the saloons at locations not greater than 7 m apart.

4.4.5 The number of and locations for impact noise measurements are to be agreed between the Builder, Owner and LR. The measurements are to be carried out when the ship is in harbour. The number and location of measurements are to take account of all different combinations of construction, areas of application, types of cabin and spaces below.

4.5 Vibration measurements

4.5.1 Vibration measurements are to be conducted in accordance with ISO 6954:1984 or ISO 6954:2000.

4.5.2 Measurements are to be made with instrumentation meeting the requirements of ISO 8041.

4.5.3 Vibration levels are to be given in terms of the velocity measurement appropriate to the version of the standard being used and should be measured over a period of not less than one minute.

4.6 Vibration measurement locations

4.6.1 Measurement locations are to be chosen so that the assessment represents the overall vibration environment onboard the ship. To minimize survey times, readings may be taken at the locations previously defined for the noise assessment part of the survey.

4.6.2 In cabins, vibration readings are to be taken in the centre of the floor area. The measurements are to indicate the vibration of the deck structure. In large spaces, such as restaurants, sufficient measurements are required to define the vibration profile.

4.6.3 Where deck coverings make transducer attachment impracticable, use of a small steel plate having a mass of at least 1 kg, with spikes as appropriate, is permissible.

4.6.4 At all locations, vibrations in the vertical direction are to be assessed. Sufficient measurements in the athwartships and fore and aft directions are to be taken to define global deck vibrations.

4.7 Approved technical organisation

4.7.1 An approved technical organisation for the purposes of these Rules is one that is acceptable to the Owner and LR with proven capability in noise and vibration measurement and satisfies all the criteria set out below:

(a) Have instrumentation whose calibration, both before and after the measurements, can be traced back to National Standards and, hence, back to International Standards.
(b) Have analysis procedures capable of data reduction to the requirements and standards set out in these Rules.
(c) Be able to provide a written report in English with contents as defined by Section 5.

■ *Section 5* Noise and vibration survey reporting

5.1 General

5.1.1 Prior to survey, a noise and vibration measurement plan is to be agreed by the Owner, Builder and LR.

5.1.2 The survey report is to comprise the data and analysis for both noise and vibration and is to be submitted to LR for consideration.

5.1.3 The survey report is to be prepared by the organisation undertaking the trial measurements, which may be an approved technical organisation or LR.

5.1.4 The survey report is to be submitted to LR's London Office for evaluation and confirmation that the results are in accordance with the noise and vibration levels specified in these Rules and/or agreed between the Owner and Builder. The assignment of a Class Notation or the issue of a Statement of Compliance will be subject to confirmation by LR.

5.2 Noise

5.2.1 The reporting of results is to comply with ISO 2923, and is to include:

(a) Measurement locations indicated on a general arrangement plan including, where possible, the measured dB(A) level.
(b) Tabulated dB(A) noise levels, together with octave band analysis for positions where the level exceeds the specified criterion by 3 dB(A), or where subjectively annoying low frequency or tonal components were present. The Noise Rating number is also to be given where octave band analyses have been conducted.
(c) Ship and machinery details.
(d) Trial details:
    - Loading condition.
    - Machinery operating condition.
    - Speed.
    - Average water depth under keel.
    - Weather conditions.
    - Sea state.
(e) Details of measuring and analysis equipment (e.g. manufacturer, type and serial numbers), including frequency analysis parameters (e.g. resolution, averaging time, window function).
(f) Copies of the relevant instrument calibration certificates, together with the results of field calibration checks.

5.3 Vibration

5.3.1 The report is to contain the following information:

(a) Measurement positions indicated on a general arrangement plan.
(b) Where ISO 6964:2000 is used, the frequency-weighted overall r.m.s. vibration levels tabulated for all measurement locations calculated using the weighting functions and methodology stated in the standard.
(c) Where ISO 6954:1984 is used, the maximum peak vibration levels and their corresponding frequencies taken from the frequency spectra, tabulated for all measurement locations.
(d) Ship and machinery details.
(e) Trial details:
    - Loading condition.
    - Machinery operating condition.
    - Speed.
    - Average water depth under keel.
    - Weather conditions.
    - Sea state.
(f) Frequency analysis parameters (e.g. resolution, averaging time and window function), if the analysis is done in the frequency domain.
(g) Copies of the relevant instrument calibration certificates, together with the results of field calibration checks.

■ *Section 6* Non periodical survey requirements

6.1 Class notation assignment

6.1.1 Where the assignment of a Class Notation or a Statement of Compliance is requested, an Initial Survey is to comprise sea trial or initial in-service testing, reporting and assessment against the criteria set out in these Rules.

6.1.2 The sea trial or initial in-service testing requirements are set out in Section 4, and are to be reported in accordance with Section 5 and evaluated against the requirements of Sections 2 and 3.

6.2 Maintenance of class notation through-life and following modifications

6.2.1 Where an Owner has requested assignment of a Class Notation, arrangements are to be agreed between LR and the Owner to record observations/ complaints of excessive noise and vibration that have been such as to disturb the comfort of passengers and crew. The records of the observations are to be made available to the attending LR Surveyor at each Annual Survey.

6.2.2 Where the observations indicate that the noise and/or vibration levels may exceed the criteria relating to the Class Notation requirements and those measured at the Initial Survey, a measurement programme is to be agreed between the Owner and LR and measurements taken in accordance with these Rules.

6.2.3 A Renewal Survey may be required following modifications, alterations or repairs including replacement of major machinery items. It is the responsibility of the Owner to advise LR of such modifications.

■ *Section 7*
Referenced standards

7.1 Noise

7.1.1 The following National and International Standards for noise are referred to in these Rules:

- ISO 2923*, Acoustics – Measurement of noise on board vessels.*
- ISO 717/1*, Acoustics – Rating of sound insulation in buildings and of building elements; Part 1: Airborne sound insulation.*
- ISO 717/2*, Acoustics – Rating of sound insulation in buildings and of building elements: Part 2: Impact sound insulation.*
- IMO Resolution A.468(XII)*, Code on noise levels on board ships.*
- *IEC Publication 651, Sound level meters.*
- ISO 140/4*, Acoustics – Measurement of sound insulation in buildings and of building elements; Part 4: Field measurements of airborne sound insulation between rooms.*
- ISO 140/7*, Acoustics – Measurement of sound insulation in buildings and of building elements; Part 7: Field measurements of impact sound insulation of floors.*

7.2 Vibration

7.2.1 The following National and International Standards for vibration are referred to in these Rules:

- ISO 6954:1984, *Mechanical vibration and shock – Guidelines for the overall evaluation of vibration in merchant ships.*
- ISO 6954:2000, *Mechanical vibration and shock – Guidelines for the measurement, reporting and evaluation of vibration with regard to habitability on passenger and merchant ships.*
- ISO 8041, *Human response to vibration. Measuring instrumentation*.

RULES AND REGULATIONS FOR THE CLASSIFICATION OF SPECIAL SERVICE CRAFT

ADDITIONAL REQUIREMENTS FOR YACHTS

JULY 2008

VOLUME 3

PART 4

Lloyd's Register

Chapter Contents

Contents

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■ *Section 1* Introduction

1.1 General

1.1.1 This Part of the Rules contains the particular requirements for the construction and classification of yachts with an overall length, L_{OA} (as defined in Pt 3, Ch 1,6.2.4), of 24 m or greater, where these differ from the general Rule requirements indicated in Parts 1 to 17.

1.1.2 The regulations for the construction, classification and Periodical Survey of yachts are given in Part 1.

1.1.3 The minimum requirements in respect of intact stability for yachts are indicated in Pt 1, Ch 2,1.1.

1.1.4 Where a Load Line is to be assigned the yacht is to comply with the appropriate requirements of the National Authority or, in the absence of these, in accordance with the requirements of Chapter 2 and Pt 1, Ch 2,1.1.

1.1.5 The requirements for fire protection detection and extinction are to be in accordance with Part 17.

1.1.6 Yachts over 24 m overall length, L_{OA} (as defined in Pt 3, Ch 1,6.2.4), may be the subject of National or International regulations concerning construction, safety and manning and compliance with these regulations is the responsibility of the Owners and Builders. Lloyd's Register (hereinafter referred to as LR) is able to advise on such matters and to issue applicable certificates where so authorized by the National Authority with which the yacht is registered.

1.1.7 A yacht may take any hull form and method of propulsion described in Parts 1 to 17 of these Rules. Other hull forms or methods of propulsion will be specially considered.

1.1.8 The scantling requirements for yachts constructed from steel, aluminium alloy and composite materials are given in Parts 6, 7 and 8 respectively. Where it is proposed to construct a yacht in wood or other material not specifically covered by the Rules, such proposals will be subject to special consideration on the basis of the Rules.

1.2 Definitions

1.2.1 **Freeboard deck** is as defined in Pt 3, Ch 1,6.3.1. When a lower continuous deck is designated as the freeboard deck, that part of the hull which extends above the freeboard deck is treated as superstructure so far as concerns the application of the conditions of assignment and the calculation of freeboard. It is from this lower continuous deck that the assigned freeboard is calculated.

1.2.2 **Virtual freeboard deck** is an imaginary continuous deck which, if fitted, would enable a freeboard, calculated in accordance with the Load Line requirements, and measured from the virtual freeboard deck, that would result in a draught not less than that corresponding to the assigned freeboard. That part of the enclosed hull which extends above the virtual freeboard deck may be treated as superstructure so far as concerns the application of the conditions of assignment provided it is not less than one standard superstructure height. (*See also* Pt 3, Ch 2,7.2).

■ *Section 2* International Rating Class (IRC) Yachts

2.1 General

2.1.1 The classification of International Rating Class Yachts will be specially considered on the basis of these Rules.

■ *Section 1* General

1.1 Plans and data

1.1.1 Plans and data additional to those required by Pt 3, Ch 1,5 may be required to be submitted for appraisal, subject to the form of the yacht.

1.1.2 All plans are to be presented in a clear and unambiguous manner with sufficient details to avoid misinterpretation.

■ *Section 2* Ship side valves

2.1 General

2.1.1 Ship side valves are generally to be in accordance with Pt 15, Ch 2,3, but other materials may be considered.

2.1.2 Valves and sea chests are to be easily accessible and permanently marked. Valves not easily accessible are in addition to be fitted with remote control.

■ *Section 3* Anchor stowage

3.1 General

3.1.1 Where anchors are mounted on stemhead fittings, suitable local sheathing or protection is to be provided in areas where the anchor can make contact with the hull or deck, further precautions are to be taken to minimize hull damage in the event of a collision. The fittings are to be of substantial construction and well secured to the hull and deck.

3.1.2 Details of stemhead fittings incorporating forestay attachments are to be submitted for approval.

■ *Section 4* Bathing and watersport platforms and shell openings

4.1 General

4.1.1 Shell doors including bathing and watersport platforms, are generally to be fitted with a sill not less than 600 mm above the design waterline. All openings are to open into a watertight space with access into the yacht by watertight doors capable of being operated from both sides. The outer shell doors may be of a single or double leaf type with either hand or hand and hydraulic operated door clips to ensure watertightness when at sea. Any locking devices fitted are to 'fail safe' in the event of hydraulic failure. Provision is to be made for doors to be closed and locked by hand in the event of hydraulic failure, *see* Pt 3, Ch 4.

4.1.2 Shell openings with a sill height below, or less than 600 mm above, the design waterline are to be of equivalent structural integrity to the surrounding hull structure. Doors from this space providing internal access are to have a sill height at least 600 mm above the design waterline.

4.1.3 Drainage systems for the above shell openings are to be fitted with non-return valves.

4.1.4 Transom platforms are to be integral with the hull or be separate mechanically secured components.

4.1.5 Integral components are to have scantlings equivalent to the adjacent structure with care taken to ensure continuity of strength with no hard spots.

4.1.6 Separate mechanically secured components are to be of substantial construction and securely fastened to the main structure ensuring bolting and sealing arrangements are satisfactory with no hard spots.

4.1.7 Recesses for passerelles, windlasses, platforms, cockpits, etc., are to be watertight and of equivalent strength to that of the surrounding hull and deck structure with care being taken to ensure continuity of strength. Electrical and hydraulic penetrations (where fitted) are to be through watertight glands. Direct overboard discharges are to be fitted to prevent any accumulation of water in the recess.

■ *Section 5* Deck safety equipment

5.1 General

5.1.1 Sailing yachts are, in general, to be fitted with a pulpit, pushpit and guard wires with hand rails inboard to assist personnel movement around the upper deck. Motor yachts are, in general, to be fitted with bulwarks and/or guard rails.

5.1.2 The size, height and position of bulwarks, pulpit, pushpit and guard rails or wires and the securing points for handrails and lifelines are to be in accordance with National or International Standards, *see also* 6.9. The scantlings and securing arrangements are to be designed to withstand the maximum load that could be exerted upon them in service, details of which are to be indicated in the relevant plans.

5.1.3 Doors fitted in bulwarks are to be of equal strength to the adjacent bulwarks and be capable of being secured closed at sea.

■ *Section 6* Protection of openings

6.1 General

6.1.1 Closing appliances for yachts are, in general, to provide weathertight integrity and safety equivalent to the requirements of Pt 3, Ch 4 taking into consideration reductions depending on the height of the lowest weatherdeck, relative to the design waterline.

6.1.2 The vertical distance between the freeboard deck and the weatherdeck may be used to reduce the Load Line requirements for closing appliances, coaming heights and openings in the hull, superstructure and deckhouses.

6.1.3 The vertical distance between the virtual freeboard deck and the weatherdeck may be used to reduce the Load Line requirements for closing appliances, coaming heights and openings in the hull, superstructure and deckhouses.

6.1.4 Where this vertical distance (as defined in 6.1.2 and 6.1.3) is at least one standard superstructure height then Load Line requirements for closing appliances, coaming heights and openings apply as if an additional tier of superstructure existed. *See also* Pt 3, Ch 2 7.2.2.

6.1.5 Where this vertical distance (defined in 6.1.2 and 6.1.3) is less than one standard superstructure height the coaming heights of doors, hatches, ventilators, air pipes, etc., may be reduced in proportion to the ratio of the actual distance and one standard superstructure height.

6.2 Hinged weathertight doors

6.2.1 Doors on the weather deck (first tier accommodation) protecting direct access to machinery spaces are to be of substantial construction in accordance with or equivalent to recognised National or International Standards. They are to be permanently attached to the casing, outward opening and gasketed weathertight with a minimum of six clips and have a coaming height of 460 mm with a minimum of 230 mm depending on the excess freeboard.

6.2.2 Doors on the weather deck to first tier accommodation or other spaces protecting access below are to be as required by 6.2.1 with a minimum of four clips. Provided access to the space(s) may be obtained from the deck above, the coaming height may be 230 mm with a minimum of 150 mm depending on the excess freeboard.

6.2.3 Where wood doors are proposed on the weather deck in lieu of doors in 6.2.2 above they are to be strongly constructed of hardwood not less than 50 mm thick, double gasketed with coamings as required by 6.2.2. For doors in exposed locations additional securing arrangements by slip bolts, clamps or equivalent are required. These doors are not to be the sole means of entry or exit from the space. Where these doors may be required to be used as a means of escape in an emergency situation, the additional securing arrangements are to be operable from both sides.

6.2.4 The use of FRP for doors on the weather deck other than to machinery spaces may be accepted, providing the doors are of substantial construction in accordance with 6.2.2.

6.2.5 Proposals to use FRP doors for access to machinery spaces are to comply with 6.2.4 in addition to Part 17, in respect of fire requirements and compliance with any National Authority requirements which may be applicable.

6.2.6 Doors in the second tier accommodation are to be as indicated in 6.2.1 with a minimum of four clips, or wood doors per 6.2.3 and have a coaming height of 100 mm with a minimum of 50 mm depending on the excess freeboard. Sliding doors with equivalent securing arrangements may be accepted.

6.3 Hatches (coamings and covers)

6.3.1 Hatches on the weather deck and deck above are to have a structural integrity of not less than the structure to which they are fitted and are to be weathertight when closed.

6.3.2 Hatches on the weather deck in the forward 0,25L_L or to machinery spaces are to be hinged on the forward side and have 460 mm coamings with a minimum of 230 mm depending on the excess freeboard.

6.3.3 Elsewhere on the weather deck, hatches which are proposed to be open at sea and provide access to lower accommodation spaces are to have a coaming height of 230 mm with a minimum of 150 mm depending on the excess freeboard.

6.3.4 Hatches on the deck above the weather deck which are proposed to be open at sea, are to have a coaming height of 150 mm with a minimum of 50 mm depending on the excess freeboard.

6.3.5 Flush hatches that are not closed by gasketed covers and secured by close space bolts will be specially considered but should not, in general, be fitted on the weather deck. However, flush hatches fitted with double gasketed covers with drains led overboard that do not require to be opened at sea and that are in protection locations, will be considered.

6.3.6 Escape hatches are to be operable from both sides.

6.4 Ventilators and air pipes

6.4.1 Ventilators and air pipes are to have coamings complying with Pt 3, Ch 4,11 and Pt 15, Ch 2,11 respectively.

6.4.2 Where necessary for operational reasons, coamings on the weather deck protected by the bulwark, may be reduced to the bulwark height subject to a minimum coaming height of 450 mm for ventilators and 300 mm for air pipes.

6.5 Portlights and windows

6.5.1 The requirements for side scuttles and windows are indicated in Pt 3, Ch 4. Proposals to fit windows below freeboard deck will be specially considered.

6.5.2 Round, elliptical or elongated portlights are to have a structural integrity of not less than the structure to which they are fitted. If fitted below the weatherdeck they are to be provided with permanently attached deadlights. *See also* Pt 3, Ch 4,7.12.2.

6.5.3 Where internal covers are provided, they are to be gasketed and capable of being secured weathertight (with additional backing bars if necessary). Provision is to be made for the storm covers to be stored on board and their stowage location noted in the document ‘For the information of the Master’. Internal storm blinds may be accepted subject to satisfactory tests being carried out.

6.5.4 Chemically toughened glass may be used in lieu of thermally toughened glass provided it can be demonstrated the strength of the arrangement is at least equivalent in strength to that of thermally toughened glass. The glazing system is to be of laminated construction and the method of testing will be specially considered.

6.5.5 Wheelhouse windows are to be of toughened safety glass, or where they are of laminated or sandwich construction, the surface layers are to be of toughened safety glass.

6.5.6 Details of the attachment of windows in their frames and of frames to the yacht structure are to be submitted for approval.

6.5.7 Storm covers or deadlights are required for all windows and portlights in the front of the deckhouse on the weather deck and also the sides, except where these are interchangeable port and starboard; in this case a sufficient number to fit any one side are to be provided. Additionally a storm cover or deadlight is to be provided for each different size of window or portlight respectively.

6.5.8 A glazing equivalent may be fitted in lieu of deadlights or stormcovers on the weather deck and above. The thicknesses and arrangements are to be acceptable to the National Authority with whom the craft is registered and/or by the Administration within whose jurisdiction the ship is intended to operate. For arrangements of glazing acceptable to Lloyd’s Register (hereinafter referred to as LR), *see* Table 2.6.1. Alternative arrangements of glazing in lieu of deadlights or storm covers may be accepted provided details are submitted for consideration.

6.6 Sliding glass doors or glass walls

6.6.1 When sliding glass doors are provided, or a glass wall which includes an access, an alternative access, or exit from the space, is to be provided, and the arrangements are to be in accordance with approved plans and weathertight commensurate with their position. Coaming heights are, in general, to be in accordance with 6.2 and the use of portable coamings will be considered. Details are to be submitted.

6.6.2 The glass used in the above is to be toughened safety glass or equivalent in accordance with 6.5.

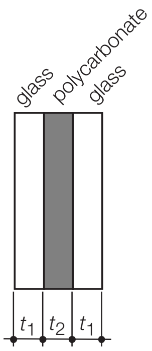
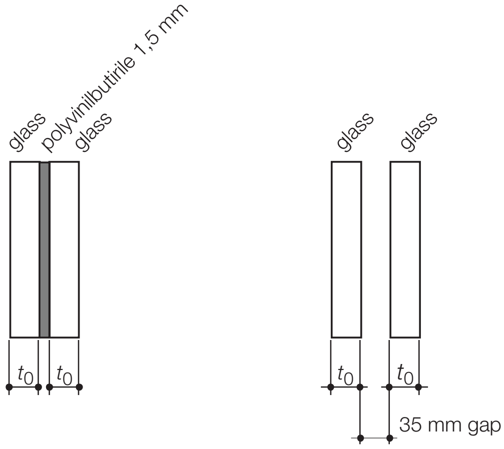
6.6.3 Storm covers of strong construction are to be provided and stored on board. Aft facing glass doors or walls in the second tier and above, are not required to be fitted with storm protection. The use of a virtual freeboard deck to determine storm cover requirements is not permitted. Additional portable supports are to be provided as necessary and full details are to be submitted for approval. Roller shutters or other alternatives will be specially considered.

6.6.4 In lieu of a weathertight coaming for the cover, adequate drainage is to be provided between the cover and the glass which may be in the form of a sump drained overboard, with a grating over, details of such proposals should be submitted for individual consideration.

6.7 Scuppers and sanitary discharges

6.7.1 Piping and valves are, in general, to comply with the requirements indicated in Pt 15, Ch 2,3.

Table 2.6.1 Acceptable arrangements of glazing in lieu of portable storm covers/deadlights

In lieu of portable storm covers	In lieu of deadlights or storm covers
 $t_1^2 + (0{,}77t_2)^2 + t_1^2 = (1{,}2t_0)^2$	
Symbols	
t_0 = minimum thickness of toughened glass as calculated in Pt 3, Ch 4,7.8.1.	

6.8 Freeing ports

6.8.1 In general, freeing ports are to be in accordance with the requirements indicated in Pt 3, Ch 4, taking into consideration the position of the virtual freeboard deck indicated in 6.1.

6.9 Bulwarks, guard rails and wires

6.9.1 Bulwarks, guard rails and wires are in general, to comply with the requirements indicated in Pt 3, Ch 4,8.

6.9.2 Where a bulwark of reduced height is fitted, guard rails or wires are to be provided above the bulwark to a height of 1000 mm above the deck.

6.9.3 Where the proper working of a yacht may otherwise be impeded bulwarks, guard rails of wires of a reduced height may be considered. Details are to be submitted for approval.

6.9.4 Protection is to be provided in way of boats, liferafts, etc.

■ *Section 7* Corrosion protection

7.1 General

7.1.1 The design of the structure and methods of attachment of fittings are to take into consideration procedures to minimize corrosion of metal structures and fittings due to electro-chemical action. All exposed steel and aluminium alloy surfaces are to be protected by the application of a suitable paint and anti-fouling system and the fitting of a cathodic or impressed current protection system.

7.1.2 Sacrificial anodes are to be mounted equidistant between metals being protected, and their location and attachment is to be such as to obviate hard spots.

7.1.3 Anodes with cast-in galvanised steel straps are to be secured to the steel hull by welded studs or direct welding.

7.1.4 The design and performance characteristics of the cathodic protection system is the Builder's responsibility. Particular attention is to be given to the earth bonding system, to provide good electrical continuity.

7.1.5 Yachts fitted with a negatively grounded electrical system or fitted with a negatively grounded independent battery system may use the impressed current cathodic protection scheme.

7.2 Protection – Aluminium alloy yachts

7.2.1 Anti-fouling paints containing copper are not to be used.

7.2.2 Bilges and internal surfaces subject to salt laden air are to be coated with a waterproof mastic or equivalent.

7.2.3 Particular attention is to be given to the design and selection of materials used for underwater fittings and the associated piping systems to limit the effect of bimetallic corrosion. Where materials other than aluminium are used they are, in general, to be electrically insulated from the hull and internal metal piping or cathodically protected separately by anodes attached directly to such fittings.

7.3 Protection – Composite yachts

7.3.1 Aluminium alloy or steel sterndrives, waterjet units and trim tabs are to be cathodically protected by anodes mounted on the hull, direct to the unit being protected or through the bonding system.

■ *Section 8* Intact stability

8.1 Application

8.1.1 The requirements of this Section apply to all yachts with an overall length, L_{OA}, of 24 m or greater, *see* Pt 1, Ch 2,1.1.13. Consideration will be given to the acceptance of stability requirements that have been prescribed and approved by the Flag State, provided they are deemed by LR to provide an acceptable level of safety.

8.2 General

8.2.1 The Rules are based on the appropriate parts of the IMO Code on Intact Stability for All Types of Ships covered by IMO Instruments, IMO Resolution A.749(18).

8.2.2 *See* Ch 3,10 for additional requirements for sailing yachts.

8.3 Stability booklet

8.3.1 Each yacht is to be provided with an approved stability booklet which contains sufficient information to enable the master to operate the yacht in compliance with the applicable requirements of the Rules.

8.3.2 Detailed guidance regarding format and content of the stability booklet may be found in IMO Resolution A.749(18), 2.1.3 and MSC/Circ. 456.

8.3.3 Guidance to the master given in the stability booklet, regarding general precautions against capsizing and procedures related to severe weather conditions, is to include notes based on the appropriate Parts of 2.3 and 2.5 of IMO Resolution A.749(18).

8.4 Fixed ballast

8.4.1 If used, fixed ballast is to be installed under the supervision of LR and in a manner that prevents shifting of position. Fixed ballast is not to be removed from the yacht or relocated within the yacht without the approval of LR.

8.5 General intact stability criteria

8.5.1 The area under the righting lever curve (*GZ* curve) is to be not less than 0,055 metre-radians up to (θ = 30° angle of heel) and not less than 0,09 metre-radians up to (θ = 40° or the angle of flooding, θ_f,if this angle is less than 40°). Additionally, the area under the righting lever curve (*GZ* curve) between the angles of heel of 30° and 40°, is to be not less than 0,03 meter-radians. θ_f is an angle of heel at which openings in the hull, superstructures or deckhouses, which cannot be closed weathertight, immerse. In applying this criterion, small openings through which progressive flooding cannot take place need not be considered as open.

8.5.2 The righting lever *GZ* is to be at least 0,20 m at an angle of heel equal to or greater than 30°.

8.5.3 The maximum righting arm is to occur at an angle of heel preferably exceeding 30° but not less than 25°.

8.5.4 The initial metacentric height GM_0 is to be not less than 0,15 m.

8.5.5 The angle of heel on account of crowding of guests to one side as defined in paragraphs 8.10.1 to 8.10.4 is not to exceed 10°.

8.5.6 The angle of heel on account of turning is not to exceed 10° when the heeling moment determined by the following formula is applied:

$$M_H = (0,02V_0^2\, \Delta\, (KG - 0,5T_m))/L_{WL} \text{ m tonnes}$$

where

KG = height of centre of gravity above keel, in metres
L_{WL} = length of yacht at waterline, in metres
M_H = heeling moment, in metre-tonnes
V_0 = service speed, in metres per second
T_m = mean draught, in metres
Δ = displacement, in tonnes.

8.5.7 Where anti-rolling devices are installed in a yacht, LR is to be satisfied that the above criteria can be maintained when the devices are in operation.

8.5.8 A number of influences such as beam wind on yachts with large windage area, icing of topsides, water trapped on deck, rolling characteristics, following seas, etc., adversely affect stability and these are to be taken into account, so far as is deemed necessary by LR.

8.5.9 Provisions are to be made for a safe margin of stability at all stages of the voyage, regard being given to additions of weight, such as those due to absorption of water and to losses of weight due to consumption of fuel and stores.

8.6 Severe wind and rolling criteria

8.6.1 Where in any loading condition the mean height of the profile area above the waterline is greater than 30 per cent of the beam of the yacht, the curve of statical stability is to include a superimposed wind heeling moment curve, in accordance with IMO Resolution A.749(18), Section 3.2.

8.6.2 Where a reduced wind pressure may be justified, the value of *P* in paragraph 3.2.2.2 of IMO Resolution A.749(18) may be reduced, subject to the agreement of the plan approval office. The yacht's operational envelope will include details of any service limitations.

8.7 Effect of free surfaces of liquids in tanks

8.7.1 For all loading conditions, the initial metacentric height and the righting lever curve are to be corrected for the effect of free surfaces of liquids in tanks.

8.7.2 For guidance on correcting for free surface effects reference may be made to 3.3 of IMO Resolution A.749(18) and 4.5 of MSC/Circ. 456.

8.8 Assessment of compliance with stability criteria

8.8.1 For the purpose of assessing whether the stability criteria are met, stability curves are to be drawn for the main loading conditions intended by the designers/Builders in respect of the yacht's operations.

8.9 Standard conditions of loading to be examined

8.9.1 The Standard conditions of loading to be examined are:

(a) Yacht in the fully loaded departure condition (to Loadline marks of Load Line assigned, otherwise to deepest design draught) with full stores and fuel and with the full number of crew and guests with their luggage.

(b) Yacht in the fully loaded arrival condition, with full number of crew and guests and their luggage, but with only 10 per cent stores and fuel remaining.

8.10 Assumptions for calculating loading conditions

8.10.1 A weight of 75 kg is to be assumed for each guest or crew member.

8.10.2 The height of the centre of gravity for persons is to be assumed equal to:

(a) 1,0 m above deck level for persons standing upright. Account may be taken, if necessary, of camber and sheer of deck;

(b) 0,30 m above the seat, in respect of seated persons.

8.10.3 Guests and luggage are to be considered to be in the spaces normally at their disposal, when assessing compliance with the criteria given in 8.5.1 to 8.5.4.

8.10.4 Guests without luggage are to be considered as distributed to produce the most unfavourable combination of heeling moment and/or initial metacentric height, which may be obtained in practice, when assessing compliance with the criteria given in 8.5.5 and 8.5.6 respectively. Distribution density need not be greater than four persons per square metre.

8.11 Calculation of stability curves

8.11.1 Hydrostatic and stability curves are, in general, to be prepared on a design trim basis. Where the operating trim or the form and arrangement of the yacht is such that change in trim has an appreciable effect of righting arms, such change in trim is to be taken into account.

8.11.2 In cases where the yacht would sink due to down-flooding through any openings, the stability curve is to be cut short at the corresponding angle of flooding, after which the yacht is to be considered to have entirely lost its stability.

8.12 Inclining test

8.12.1 On completion of construction each yacht is to undergo an inclining test to determine the actual displacement and co-ordinates of the position of the centre of gravity of the yacht.

8.12.2 Subject to any National requirements which may apply, the inclining test for an individual yacht may be dispensed with, provided basic stability data derived from the inclining of a sister yacht are demonstrated to be valid for the exempted yacht by carrying out a satisfactory lightweight check. LR agreement is to be obtained for such dispensation.

■ *Section 9* Damage stability

9.1 Application

9.1.1 The requirements of this Section apply to all yachts that are 500 gt or more.

9.1.2 Consideration will be given to the acceptance of damage stability requirements that have been prescribed and approved by the Flag State, provided they are deemed by LR to provide an acceptable level of safety.

9.2 Requirements

9.2.1 Sufficient intact stability is to be provided in all service conditions so as to enable the yacht to withstand the final stage of flooding within any one main compartment, bounded by watertight subdivision bulkheads.

9.2.2 The above requirement is to be determined by calculations in accordance with 9.3, 9.4 and 9.6 which take into consideration the proportions and design characteristics of the yacht and the arrangement and configuration of the damaged compartments.

9.2.3 Where it is proposed to fit decks, inner skins or longitudinal bulkheads of sufficient tightness to restrict the freeflow of water, guidance is to be obtained from LR regarding the treatment of such restrictions in the calculations.

9.2.4 In cases where LR considers the range of positive stability in the damaged condition to be inadequate, it may require further investigation.

9.3 Permeability

9.3.1 For the purpose of making damage stability calculations the volume and space permeabilities are, in general, to be in accordance with Table 2.9.1.

Table 2.9.1 Permeability

Spaces	Permeability
Appropriated to cargo or stores	60
Occupied by accommodation	95
Occupied by machinery	85
Intended for liquids	0 or 95 (*see* Note)
NOTE Whichever results in the more severe requirements.	

9.3.2 Where it is demonstrated to the satisfaction of LR that the permeability of a given space, determined by detailed calculation, is less than that given in 9.3.1, the calculated value may be used.

9.4 Damage extent

9.4.1 The assumed extent of damage is to be as follows:

(a) Longitudinal extent: 3,05 metres plus three per cent of the length, L_R, of the yacht.

(b) Transverse extent (measured inboard from the yacht's side, at right angles to the centre line at the level of the deepest subdivision load line): a distance of one fifth of the breadth, *B*, *see* Pt 3, Ch 1,6.2.5 of the yacht.

(c) Vertical extent: from the base line upwards without limit.

(d) If any damage of lesser extent than that indicated in 9.4.1(a), (b) and (c) would result in a more severe condition regarding heel or loss of metacentric height, such damage is to be assumed in the calculations.

9.5 Unsymmetrical flooding

9.5.1 Unsymmetrical flooding is to be kept to a minimum consistent with efficient arrangements. Where it is necessary to correct large angles of heel, the means adopted are, where practicable, to be self-acting, but in any case where controls to cross-flooding fittings are provided they are to be operable from above the bulkhead deck. These fittings together with their controls are to be acceptable to LR. The maximum angle of heel after flooding but before equalisation is not to exceed 15°. Where cross-flooding fittings are required the time for equalisation is not to exceed 15 minutes. Suitable information concerning the use of cross-flooding fittings is to be supplied to the master of the yacht. *See* the Recommendation on a Standard Method for Establishing Compliance with the Requirements for Cross-Flooding Arrangements in Passenger Ships, adopted by the IMO by Resolution A.266(VIII).

9.6 Survival criteria

9.6.1 The final conditions of the yacht after damage and, in the case of unsymmetrical flooding, after equalisation measures have been taken are to be as follows:

(a) In the case of symmetrical flooding there is to be a positive residual metacentric height.

(b) In the case of unsymmetrical flooding equilibrium angle of heel in the final stage of flooding is not to exceed 7°. A greater angle of heel may be permitted if it can be shown that positive residual stability and freeboard exists and the evacuation of the yacht will not be endangered.

(c) In no case is the weather deck to be submerged in the final stage of flooding.

9.6.2 Intermediate stages of flooding are to be investigated.

9.7 Bottom damage

9.7.1 In order to provide protection in the event of bottom damage, a double bottom structure in accordance with Pt 3, Ch 2,6.6 is to be fitted.

9.7.2 Special consideration will be given to the fitting of double bottoms in way of special features of the yacht, provided it can be demonstrated that the yacht can meet the survival criteria given in 9.6, following assumed flooding through a breach of the bottom shell.

9.8 Openings in watertight bulkheads and decks

9.8.1 The number of openings in watertight sub-divisions is to be kept to a minimum compatible with the design and proper working of the yacht. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity.

9.8.2 Doors provided to ensure the watertight integrity of internal openings which are used while at sea are to be sliding watertight doors capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead. Indicators are to be provided at the control position, showing whether the doors are open or closed, and an audible alarm is to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular attention is to be paid to minimising the effect of control system failure. Each power-operated sliding watertight door is to be provided with an individual hand-operated mechanism. It shall be possible to open and close the door by hand at the door itself from both sides.

9.8.3 As an alternative to sliding doors, special consideration will be given to the fitting of hinged watertight doors, where it can be shown that they are as effective as sliding watertight doors.

9.9 Stability information

9.9.1 The stability booklet required by 8.3.1 is to include, where appropriate, any special instructions relevant to ensuring compliance with the damage stability standard, e.g. details of the operation of cross-flooding arrangements.

9.9.2 In addition a plan is to be supplied showing down flooding points and any doors or other openings in watertight bulkheads which require to be closed to achieve the damage stability standard.

■ *Section 10*
Navigation in first-year ice conditions

10.1 General

10.1.1 Where additional strengthening is fitted in accordance with the requirements of Pt 6 Ch 5,7, Pt 7 Ch 5,7 and Pt 8 Ch 5,6 an appropriate special features notation will be assigned. It is the responsibility of the Owner to determine which notation is most suitable for their requirements.

10.1.2 When yachts may be expected to visit areas requiring them to navigate in light first year ice conditions other than the Northern Baltic corresponding to unbroken level ice of thickness not greater than 0,4 m, the hull is to meet the requirements necessary for the assignment of Ice Class 1D.

10.1.3 Yachts in Service Group G6, which have their own propulsion machinery, and which are built of steel but are not strengthened for navigation in ice, may be eligible for assignment of Finnish-Swedish Ice-Due Class II under the Finnish and Swedish Boards of Navigation *Finnish-Swedish Ice Class Rules*. Yachts in Service Groups G1–G4 inclusive, con-structed in any material, together with Yachts in Service Group G6 constructed in aluminium or composites are not eligible for this notation.

10.1.4 For Yachts requiring to navigate in areas of ice in excess of that specified in 10.1.2, the standard of construction is to comply with the requirements of Part 8 of the Rules for Ships as appropriate.

Section

■ *Section 1* Hull design and construction parameters

1.1 Plans and data

1.1.1 In addition to the general plans and data required by Pt 3, Ch 1,5 the following details of additional structural components, particular to sailing yachts, are to be submitted for appraisal:

- Sail plan.
- Mast loadings.
- Bowsprit loadings.
- Rigging loadings.
- Mast step.
- Mast partners.
- Ballast keel lines plan.
- Ballast keel securing arrangements.
- Rudder skeg construction and support details.
- Chainplates.
- Through deck fittings.

1.1.2 All plans are to be presented in a clear and unambiguous manner with sufficient details to avoid misinterpretation.

1.2 Mast and rigging support arrangements

1.2.1 Sailing yacht mast and standing rigging loadings and their support structure require special consideration as follows:

(a) Adequate hull and deck longitudinal structure to resist hull bending.
(b) Provision of adequate transverse structure in way of masts, chainplates, keels, skegs, etc.
(c) Provision of adequate bottom structure to support the mast and dissipate the mast loadings.
(d) Local reinforcement in way of chainplates, forestay and backstay fittings, etc.
(e) The deck and beams are to be suitably strengthened in way of masts, coachroof/deckhouse ends, windlass, cleats, sheet winches, sheet tracks, etc. Where a mast is stepped on the deck or coachroof/deckhouse the structural arrangements will be specially considered.

1.2.2 Details of the designer's/Builder's calculated maximum loads on the mast heel and the breaking loads of all standing rigging are to be submitted with the main structural plans for appraisal.

1.3 Bowsprits

1.3.1 The hull structure in way of the bowsprit is to be suitably reinforced with due account taken of the compressive loads along the bowsprit and bending moments due to rigging loads.

1.3.2 Details of the designer's/Builder's calculated maximum loads on the bowsprit and the breaking loads of all associated standing rigging are to be submitted with the structural plans for appraisal.

■ *Section 2* Hull construction

2.1 Hull scantlings (composite materials)

2.1.1 The basic structural scantlings are, unless specified within this Section, to be as indicated in Part 8.

2.1.2 The shell weight/thickness determined from Part 8, is to be maintained throughout the length of the craft, with the bottom shell weight extending to the chine line or 150 mm above the static load waterline, whichever is the greater.

2.1.3 The keel plate thickness for sailing yachts is to be 1,1 times the keel thickness for motor craft as determined in Part 8. In no case is the thickness of keel to be taken less than the thickness of the adjacent bottom shell or fin and tuck as appropriate.

2.1.4 The fin and tuck thickness is not to be less than 0,9 times the keel thickness for motor craft as determined in Part 8. In no case is the thickness of the fin and tuck to be taken less than the thickness of the adjacent bottom shell.

2.1.5 The construction of hull to deck connections is to be in accordance with Pt 8, Ch 2,5.

2.1.6 The hull laminate is to be strengthened in way of the attachment of chainplates, etc., *see* Pt 8, Ch 2,5.

2.1.7 The stern or transom is to be the same weight as the side shell and is to be adequately stiffened with special consideration being given to the transmission of backstay loadings.

2.1.8 Where twin bilge keels are fitted, the bottom laminate in way of the bilge keels is to be formed by extending the keel reinforcement to a distance not less than 25 per cent the width of the keel, as required by Part 8, outside the line of the outboard edge of the bilge keels or to the supporting structure whichever is the greater, prior to being tapered in accordance with the Rules to the adjacent bottom shell laminate. *See also* 2.1.10.

2.1.9 The hull and deck are to be locally increased in thickness in way of fittings for rudder tubes, propeller brackets etc. The increase is not to be less than 50 per cent of the adjacent plate laminate. Details of such reinforced areas are to be submitted for consideration.

2.1.10 Local reinforcement is, in general, to extend under the adjacent supporting structure and then be tapered gradually to the base laminate thickness in accordance with Pt 8, Ch 3,3.14.

2.2 Transversely framed yachts

2.2.1 Sailing yachts with a conventional rig, are to be provided with suitably increased scantlings in floors, frames, beams and brackets adjacent to each mast.

2.2.2 In general, beams at the heads of web frames and four beams in way of each mast in sailing and auxiliary yachts are to have their scantlings increased by a factor of two. Where practicable, masts are to be located in way of transverse bulkheads or other primary stiffening.

2.2.3 Keel mounted masts are to be mounted on a suitable mast step secured to three floors at a height sufficient to provide the necessary structural integrity and to keep the heel of the mast clear of any bilge water.

2.2.4 Keel mounted masts are to be fitted with mast partners running fore and aft on either side of the mast to join the transverse beams. The strength of the mast partners are to be the same as for the beams.

2.2.5 Deck mounted masts are to be housed in a mast step positioned directly over a bulkhead or a web frame/deep beams with a pillar fitted under the mast.

2.3 Longitudinally framed yachts

2.3.1 Conventional masts mounted on mast steps as in 2.2.3 are to be fitted with heavy transverse web frames as required by 2.2.2.

2.4 Yachts fitted with non-conventional rigs

2.4.1 The structure in way of non-conventional mast configurations will be specially considered.

■ *Section 3* Chain plates

3.1 General

3.1.1 Chain plates and other securing arrangements to take the loads of all standing rigging for masts and bowsprits, are to be of substantial construction and well integrated with the hull and/or deck supporting structure. They are to be of sufficient strength that, in the event of failure of the standing rigging, the watertight integrity of the hull is not impaired.

3.1.2 The breaking loads of all mast and bowsprit standing rigging together with the actual loads imposed by the rigging are to be submitted.

3.2 Calculations

3.2.1 The strength of any part of chainplates or structure to which it is attached is not to be less than the breaking load of the rigging to which it is attached and subject to the following factors of safety (FOS).

Items:	Minimum FOS:
Rigging	1,0
Lug, eyebolt eye	1,2
Lug to baseplate	1,2
Eyebolt/base plate to foundation	2,0
Chainplate to foundation (below decks)	2,0
Chainplate foundation to hull structure	2,0

■ *Section 4* Deck planking

4.1 General

4.1.1 The construction of decks of steel, aluminium alloy or composite materials is to be in accordance with Pt 6, Ch 3,8, Pt 7, Ch 3,8 and Pt 8, Ch 3,8 respectively. Wood deck sheathing is in general to be treated as cosmetic and is outside the scope of these Rules. However, any wood sheathing fitted is not to be detrimental to the integrity of the main deck structure. Details of the means of attachment of such wood sheathing are to be submitted for consideration.

4.1.2 Decks constructed of wood will be specially considered on the basis of the Rules.

Section 5 Deck fittings

5.1 General

5.1.1 Due consideration is to be given at the design stage to ensure that additional structural support, by way of pads, brackets etc., is provided in way of deck fittings such as mainsheet and genoa tracks, winches, eyebolts, sail-lead tracks, fairleads, anchor and chain cable handling and securing arrangements, grab rails, guard wires, hatch hinges, etc., which are subject to substantial loadings and or use.

5.1.2 Fittings which are subject to significant loads are, in general, to be through bolted, in single skin areas. The laminate is to be locally increased in thickness as necessary with due account taken of such loadings.

5.1.3 Details of inserts, local reinforcement and through bolting arrangements for yachts of composite construction are to be in accordance with Pt 8, Ch 2.

Section 6 Ballast keels

6.1 External ballast keel

6.1.1 The ballast keel may be of lead, cast iron or other suitable material. Cast iron or other ferrous metals are not to be used in wood or composite craft sheathed with copper or other non ferrous metal.

6.1.2 Prior to installation the ballast keel is to be 'Dry fitted' to the hull and the top is to be smooth, or slightly concave in all directions, and well coated with a suitable bedding compound.

6.1.3 In composite yachts care is to be taken to prevent crushing of GRP laminates through overtightening of keel bolts.

6.1.4 A substantial plate washer is to be fitted under the head of the keel bolt. The diameter and thickness are to be not less than 4,0 and 0,25 times the bolt diameter, respectively, but the thickness need not in general exceed 8 mm. The top of the bolt is to have sufficient thread to take double nuts or other suitable locking arrangement. *See also* 6.3.6.

6.1.5 The structure in way of the ballast keel is to be in accordance with the requirements of Parts 6, 7 and 8 for the respective material.

6.1.6 In steel/aluminium alloy yachts all bottom structure in way of the ballast keel(s) is to be welded by means of double continuous welding.

6.1.7 Ballast keels are to be fully supported by floors to distribute the keel loadings to the bottom structure, *see* Pt 8, Ch 3. The scantlings of the floors and frames will be specially considered in conjunction with the keel mass together with the size, material and position of the keel bolts.

6.1.8 Canards and lifting keels are outside the scope of the Rules but the structure in way will be specially considered with regard to maintenance of structural and watertight integrity. Full details are to be submitted for appraisal.

6.2 Internal ballast keel

6.2.1 Where ballast is to be incorporated in the keel, the internal surface is to be suitably coated prior to filling, and on completion the top surface is to be sealed.

6.2.2 For steel and aluminium alloy yachts the method of installing the internal ballast is not to be detrimental to the plating or internal structure. Details of the installation procedure are to be submitted for consideration prior to implementation.

6.2.3 Internal ballast is to be suitably supported and secured against movement. The supporting structure in way of internal ballast is to be suitably increased in strength.

6.2.4 In steel/aluminium yachts, the ballast is to be totally encapsulated by fully welded plating with a minimum thickness of 6 mm. Alternative arrangements will be specially considered.

6.2.5 In composite yachts, the internal ballast is to be encapsulated by a laminate equivalent in thickness to half the rule bottom shell laminate or 2400 g/m^2 CSM (or equivalent), whichever is the greater.

6.3 Keel bolts

6.3.1 The keel bolts are to be of a corrosion resistant material. The nuts, washers, etc., are to be of a material the same as, or compatible with, that of the keel bolts. The specifications of these materials are to be submitted for appraisal.

6.3.2 The diameter of keel bolts, d_k, is to be that determined from the following formula, or 14 mm, whichever is the greater:

$$d_k = 14{,}2 \sqrt{\frac{w\, d_{cg}}{\sigma_u\, b_k}} \text{ mm}$$

where

b_k = breadth of top of ballast keel in way of bolt, in mm

d_{cg} = vertical distance of the centre of gravity of weight, w, below top of ballast keel, in mm

w = the portion of the weight of ballast keel supported by the bolt, in kg

σ_u = ultimate tensile strength of the bolt material, in N/mm^2

When determining w for the bolt at the ends of the keel, the weight of any overhang is to be included.

6.3.3 Where double bolts are to be fitted, the total cross-sectional area of the bolts is to be not less than 1,2 times the cross-sectional area of the bolt determined in accordance with 6.3.2.

6.3.4 Keel bolts are to be fitted alternately on opposite sides of the middle line, and as close as is practicable to the bottom floor structure.

6.3.5 The ballast keel is to be secured by through bolting, but where this is not practicable, short keel bolts or studs may be fitted.

6.3.6 A substantial plate washer is to be fitted under the head of the keel bolt. The diameter and thickness are to be not less than 4,0 and 0,25 times the bolt diameter, respectively, but the thickness need not exceed 8 mm. Washer plates, where square or rectangular, are to have suitably radiused corners. In composite and wood craft the washer plates are to have all edges dressed smooth in addition to being suitably radiused.

6.3.7 The bottoms of short keel bolts are to be secured by nuts and washers fitted in pockets in the keel, or by square plate nuts cast in with the keel. Where cast in, the square plate nuts are to have a breadth and depth not less than 3,0 and 1,0 times the bolt diameter, respectively.

6.3.8 Where studs are fitted, the length of the threaded portion into the cast iron or steel keel is to be not less than 1,5 or 2,5 times the stud diameter where through tapped or blind tapped respectively.

6.3.9 It is recommended that the design of the keel bolt is such that it can be withdrawn for survey and is not cast permanently into the ballast keel.

6.3.10 Details of the proposed torque to be applied to the keel bolts is to be indicated on the relevant plans and submitted.

■ *Section 7*
Rudder skegs and rudders

7.1 Skegs

7.1.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

7.1.2 The scantlings of skegs are to be sufficient to withstand any docking forces that they may be subjected to.

7.1.3 The thickness of the skeg plating is in no case to be taken as less than 1,5 times the thickness of the adjacent bottom shell or the fin and tuck laminate whichever is the greater.

7.1.4 Where metallic sub-frames are laminated into skegs, providing transverse stiffening to the skeg and support for the rudder pintle, such stiffening members are to be fully integrated with hull framing to ensure continuity of strength.

7.1.5 The scantlings of skegs of composite construction will be specially considered on the basis of the Rules, and in this respect are to be of equivalent strength and load carrying capability to that required for skegs of steel construction from Pt 3, Ch 3,3. Due account is to be taken of the differing material properties.

7.1.6 Direct calculations may be used as an alternative to the requirements of 7.1.5 to determine the scantlings of composite skegs. Such calculations are to be submitted for appraisal.

7.2 Rudder construction arrangements

7.2.1 Rudder construction for sailing yachts is generally to be in accordance with Pt 3, Ch 3.2.

7.2.2 For use in the determination of the rudder stock diameter, within Table 3.2.7 of Pt 3, Ch 3, the factor f_c may be taken as 70 for yachts with an overall length, L_{OA}, of 24 m varying up to 79 at a length of 50 m. Intermediate values are to be determined by linear interpolation. Yachts with a length, L_R, in excess of 50 m are to comply with Table 3.2.7.

7.2.3 The rudder stock diameter is to be based upon the maximum stated operational speed of the yacht, but in no case is this to be taken less than $2{,}536\sqrt{L_{WL}}$ knots. L_{WL} is as defined in Pt 3, Ch 1,6.2.5.

■ *Section 8*
Open cockpits and companionways

8.1 Cockpit construction

8.1.1 Cockpits are to be of watertight construction with scantlings equivalent to that of the upper deck.

8.1.2 Cockpit lockers and hatches where fitted, are to be of substantial construction and are to be tested weathertight.

8.1.3 Where engine removal or other hatches are fitted in the cockpit sole they are to be watertight and bolted down. Detailed plans are to be submitted for approval.

8.1.4 The height of the cockpit sole above the waterline is to be such that the water will effectively drain overboard under all normal conditions of heel and trim.

8.2 Companionways

8.2.1 Companionway openings, are to be sited on, or as close as possible to, the centreline. Sill heights are to be not less than as required by Pt 3, Ch 4.

8.2.2 Companionway hatches are to be of substantial construction capable of being opened from both sides and be tested weathertight.

■ *Section 9* Anchoring and mooring equipment

9.1 General

9.1.1 The requirements of Pt 3, Ch 5 apply to fore and aft rigged sailing yachts of all sizes.

9.1.2 Sailing yachts with three or more masts and fitted with a square rig are to be fitted with anchors 25 per cent heavier than those calculated in accordance with Pt 3, Ch 5. Chain cable, hawsers and warps are to be increased accordingly.

9.1.3 Square rigged yachts are to have a full length of chain cable on the main anchor but may have rope with a chain tail fitted to the second anchor. Kedge anchors may be fitted using the rule length and size of warp without a chain tail.

■ *Section 10* Intact stability

10.1 General

10.1.1 In addition to the requirements of Ch 2,8, for sailing and auxiliary yachts, details are to be given in the stability information booklet of the maximum permissible heel angles whilst under sail to prevent down flooding in gusts and squalls.

10.1.2 In the absence of other National requirements, information on maximum heeling angles whilst under sail are to be based on the United Kingdom Marine Safety Agency's (UK MSA) 'Model stability information booklet for sail training ships between 15 m and 24 m in length'.

RULES AND REGULATIONS FOR THE CLASSIFICATION OF SPECIAL SERVICE CRAFT

DESIGN AND LOAD CRITERIA

JULY 2008

VOLUME 3

PART 5

Chapter Contents

Contents

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Section 1 Rule application

1.1 General

1.1.1 The global and local load and design criteria detailed in this Part are to be used in conjunction with the formulae given in Parts 6, 7 and 8 to determine the scantlings of steel, aluminium alloy and composite craft respectively as defined in Part 1.

1.1.2 The global load and design criteria given in this Part are provided to enable the designer/Builder to check global hull strength against ductile failure modes involving gross deformation. The strength calculations are, in general, to be conducted using finite element analysis techniques with a three dimensional model.

1.1.3 Load and design criteria detailed in this Part are to be supplemented by direct calculation methods incorporating model test results and numerical analysis for novel designs. Full scale measurements may be required where considered necessary by Lloyd's Register (hereinafter referred to as LR).

1.1.4 Craft built and classed in accordance with the Rules will, in general, be assigned an operational envelope. This will be based on the allowable speeds, significant wave heights and corresponding displacements. It will form an appendix to the Classification Certificate and is to be incorporated in the craft's Operational Manual. The assigned operational envelope is to be clearly displayed in the wheelhouse. Installation of an accelerometer at LCG connected via a visual display in the wheelhouse may be required.

1.1.5 The operational envelope assigned is based on the assumption that the wave height can be visually observed. Where this is not the case, the speed of the craft is to be suitably reduced.

1.1.6 The design assessment is to include a range of speeds covering all modes of operation for which the craft is designed, i.e. speeds corresponding to displacement, semi planing and fully planing. A craft which is designed to operate in the planing mode will need to be assessed using the requirements of Chapter 3 at its design speed and required significant wave height, as well as the requirements of Chapter 4 when operating at reduced speed and a more severe wave height.

1.1.7 The load design criteria given in this Part are dependent on the operating mode of the craft as follows:

- Craft operating in the **non-displacement** mode:
  - Applies to craft operating in full planing or semi-planing modes.
  - Applies to HSC at design speed. HSC is defined in Pt 1, Ch 2,2.2.8.
  - Applies to LDC at design speed. LDC is defined in Pt 1, Ch 2,2.2.10.
  - Applies to craft in foil borne mode.
  - Applies to craft where other lifting devices are actively supporting some or all of the craft's weight.
  - Typically this applies to craft with a Taylor Quotient, Γ, greater than 3. Γ is defined in Ch 2,2.1.18. However, the following is to be noted:
    - Some craft are not designed to plane, but have Γ greater than 3, e.g. SWATHs and fast displacement yachts and, unless they are classified as HSC, then these craft are to be considered as only operating in the displacement mode.
    - Some craft are designed to plane with Γ less than 3 and these should be considered as operating in the non-displacement mode.
- Craft operating in the **displacement** mode:
  - Applies to craft designed to operate in the displacement mode.
  - Applies to all other craft where they are not operating in the non-displacement mode, e.g. at lower speed in severe weather.

Section 2 Direct calculations

2.1 General

2.1.1 Direct calculations using hydrodynamic computer programs may be specifically required by the Rules. Also they may be required for craft having novel design features, or may be submitted in support of alternative load and design criteria. LR may, when requested, undertake calculations on behalf of designers and make recommendations in regard to suitability of any required model tests.

2.2 Special Service Craft Software

2.2.1 LR's direct calculation procedures and facilities are summarized in a publication entitled the LR *Software Guide*.

2.3 Submission of direct calculations

2.3.1 In cases where direct calculations have been carried out using procedures available in the LR *Software Guide* the following supporting information is to be submitted as applicable:

(a) Reference to the direct calculation procedure and technical program used.
(b) Input data.
(c) A description of the model.

(d) A summary of analysis parameters including environmental conditions, speeds and headings.
(e) Details of the weight distributions.
(f) A comprehensive summary of calculation results. Sample calculations are to be submitted where appropriate.

2.3.2 In general, all input data and output results are required to be submitted. In such cases, magnetic media with agreed format may be used for submission.

2.3.3 The responsibility for error free specification and input of program data and the subsequent correct transposal of output rests with the designer/Builder.

■ *Section 3* Model experiments

3.1 General

3.1.1 Model experiments and theoretical calculations may be required to be carried out for new design concepts and the results are to be provided when plans are submitted for approval.

3.1.2 Where model testing is undertaken, the following details are to be submitted:
(a) A summary of the model construction and its instrumentation, including calibration of instruments.
(b) A summary of the testing arrangements and procedures.
(c) A summary of the tank facilities and test equipment.
(d) Details of the wave generation, response measurements, definitions and notations.
(e) Details of data recording, reduction and data analysis procedures.
(f) Details of calibration procedures with theoretical computations.
(g) Tabulated and plotted output.

3.2 Model test matrix

3.2.1 Where model testing is undertaken, the minimum test matrix shown in Table 1.3.1 is required to be carried out.

Table 1.3.1 Minimum test matrix

Item	Test matrix
Sea state	Regular and irregular seas
Heading	Beam, head, stern and quartering seas
Speed	Three speeds including zero and maximum service speeds
Wave frequency	Six frequencies

3.2.2 In addition to those quantities which are normally measured in a model experiment, the following data are to be obtained where practicable:
(a) Vertical accelerations at the LCG, bow and stern.
(b) Acceleration loads due to heave and pitch.
(c) Vertical bending moment.
(d) Bow impact pressures at full forward speed.
(e) Oblique sea loads inducing dynamic torque on the cross structure for multi-hull craft.
(f) Splitting loads due to beam seas and roll motion for multi-hull craft.
(g) Impact pressures in tunnel side and top for multi-hull craft.

3.2.3 The basis on which the parameters are chosen for investigation is to be submitted for approval.

3.2.4 Results from open water model experiments and full scale measurements may be accepted and full details are to be submitted for appraisal.

Section

■ *Section 1* Environmental conditions

1.1 General

1.1.1 This Chapter contains information regarding the derivation of load criteria which are to be used for the computation of local design criteria in Chapters 3 and 4.

1.1.2 Environmental conditions include natural phenomena such as wind, wave and currents from which design data are to be derived.

1.1.3 These environmental conditions are usually described by physical variables of statistical nature.

1.1.4 The load criteria used for design are to be based on environmental data for the specific area and operation of the craft.

1.1.5 The loads imposed by the environment are to be based on extreme conditions. These arise as the craft advances in a seaway and is loaded and stressed in a random manner by dynamic forces and moments.

1.1.6 The load criteria given here are derived from experimental and theoretical studies complemented with service experience.

1.1.7 Alternative methods of establishing the load criteria will be specially considered, provided that they are based on model tests, full scale measurements or generally accepted theories. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

■ *Section 2* Definitions and symbols

2.1 Parameters to be used for the determination of load and design criteria

2.1.1 **Air gap.** The air gap, G_A, is the minimum vertical distance, in metres, from the static waterline to the point considered in an operational condition. In no case is G_A to be taken greater then $G_{A(max)}$ as indicated in Fig. 2.2.1.

2.1.2 **Allowable speed *V*.** The allowable speed used in the computation of environmental loads is the design speed, in knots, associated with a nominated operational environment in which the craft is certified at corresponding operational displacement.

2.1.3 **Beaufort Number.** Beaufort Number is a measure of wind strength.

2.1.4 **Bilge tangential point.** For craft with partially submerged hull(s), the bilge tangential point is defined as the tangential point of the bilge with an oblique line sloped at 50° to the horizontal at the LCG, *see* Fig. 2.2.2. For craft with fully submerged hull(s), the bilge tangential point is defined as the intersection points between the hull and the design waterline.

2.1.5 **Deadrise angle.** For craft with no clearly defined deadrise angle at the LCG, the angle, in degrees, to the horizontal of the line at the LCG formed by joining the lowest point of the hull or underside of keel and the bilge tangential point is to be taken as the deadrise angle θ_D, *see* Fig. 2.2.2. For craft with hulls of asymmetric section, where the inner and outer deadrise angles differ, the smaller of the two angles is to be used. For craft with fully submerged hull with circular sections, the deadrise angle is to be taken as 30°.

2.1.6 **Displacement mode.** Displacement mode means the regime, whether at rest or in motion, where the weight of the craft is fully or predominantly supported by hydrostatic forces.

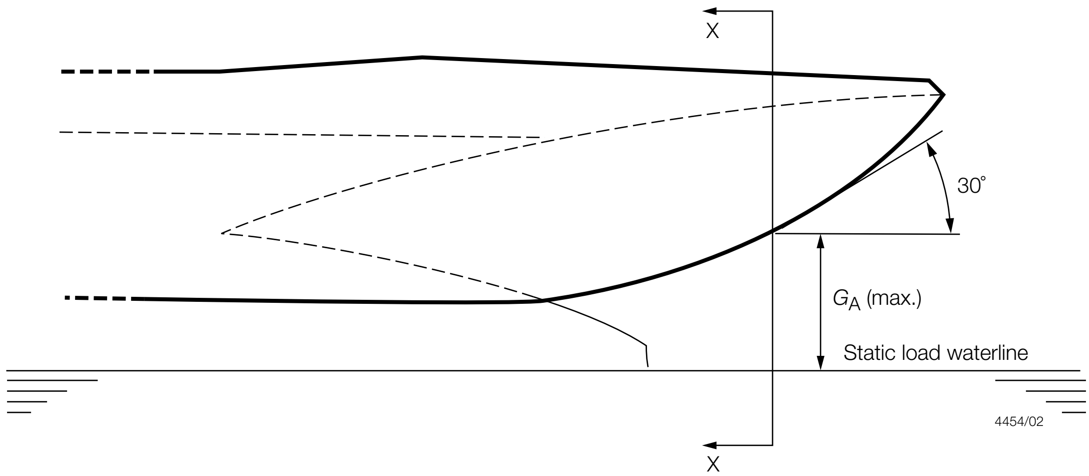
2.1.7 **Froude Number F_n.** The Froude Number is a non-dimensional speed parameter and is defined as:

$$F_n = \frac{0{,}515 V_m}{\sqrt{g\, L_{WL}}}$$

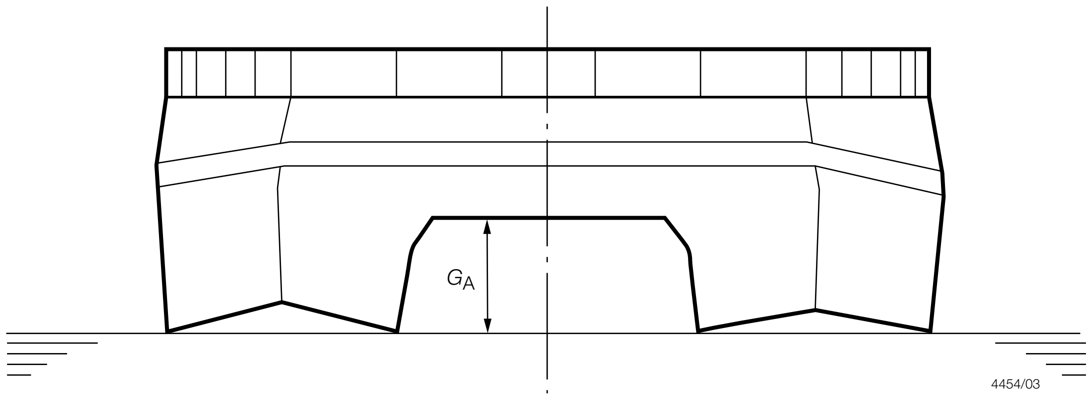
where
g is the acceleration due to gravity and is taken to be 9,81 m/s^2.
L_{WL} is defined in 2.1.19.
V_m is the appropriate speed in knots.

2.1.8 **LCG.** The LCG is the longitudinal centre of gravity of the craft in the loading condition under consideration.

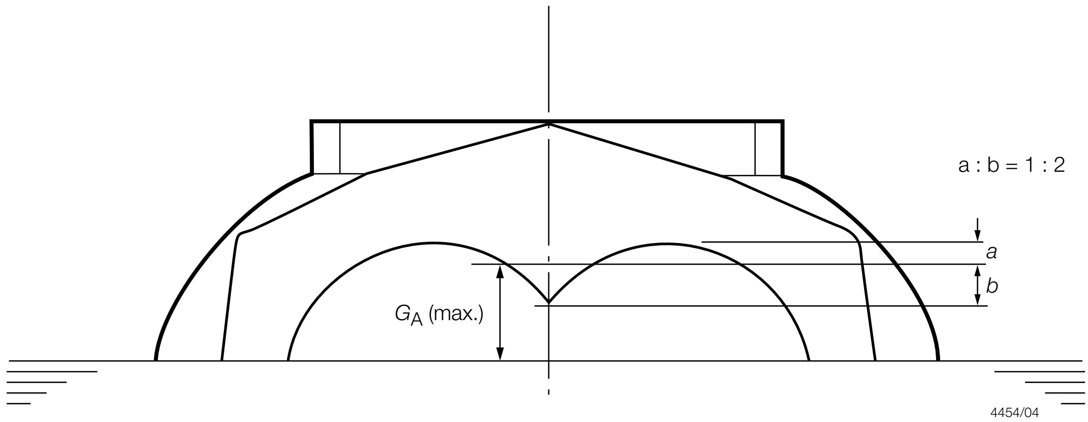
2.1.9 **Maximum wave height.** In general the maximum wave height, in metres, will be taken as 1,667 times the significant wave height. Where, for design purposes, a wave length is required this will be taken as the waterline length subject to any restriction resulting from limiting height to length ratio and wave profile angle.



Elevation on Centreline



Section at X – X : Conventional Catamaran



Section at X – X : Wave Piercing Catamaran

Fig. 2.2.1 Definition of air gap

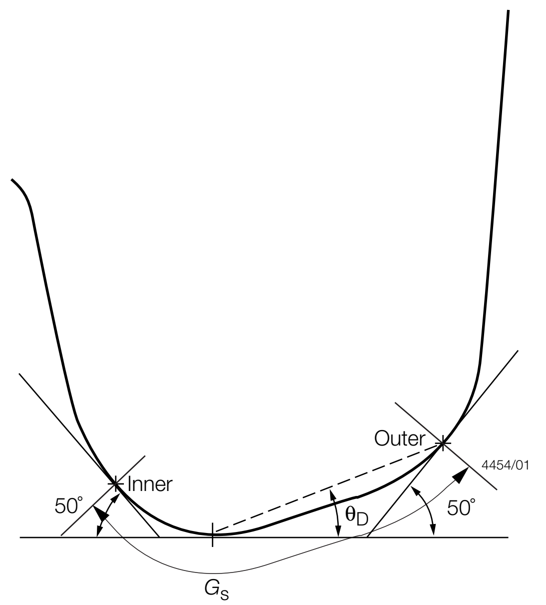


Fig. 2.2.2
Definition of bilge tangential point and G_s for craft with partially submerged hulls

2.1.10 **Non-displacement mode.** Non-displacement mode means the normal operational regime of a craft when non-hydrostatic forces substantially or predominantly support the weight of the craft.

2.1.11 **Operating waterline** is the waterline for the operating condition under consideration.

2.1.12 **Period.** The period is defined as the average time interval between upward crossings of the mean value.

2.1.13 **Sea state.** Sea state is an expression used to categorise wave conditions and is normally defined by sea spectrum, significant wave height and period distribution.

2.1.14 **Significant wave height $H_{1/3}$.** The wave height, in metres, used in the determination of craft motions and loads is a significant wave height, $H_{1/3}$, defined as the average of the one third highest waves in a short term wave measurement record.

2.1.15 **Support girth.** The support girth, G_s, is the girth distance, in metres, measured around the circumference of the shell plate between the tangential points or chines, as appropriate, of the hull for a mono-hull craft. For multi-hull craft it is to be taken between the inner and outer bilge tangential points or chines of the individual hulls. *See* 2.1.4 and Fig. 2.2.2.

2.1.16 **Surviving wave height H_{03}.** The wave height, in metres, used in the determination of the structural integrity of a craft and is defined as the wave height with three per cent probability of exceedance. If this value is unknown, the following equation is to be used to determine H_{03}:

$$H_{03} = 1{,}29 H_{1/3}$$

2.1.17 **Taylor Quotient Γ.** The Taylor Quotient is defined as:

$$\Gamma = \frac{V}{\sqrt{L_{WL}}}$$

where V is defined in 2.1.2 and L_{WL} is defined in 2.1.19.

2.1.18 **Volumetric speed number F_v.** The Volumetric speed number is defined as:

$$F_v = 7{,}19\ \nabla^{1/6}$$

where ∇ is the moulded displacement, in m^3, of the craft corresponding to the design waterline.

2.1.19 **Waterline length.** Waterline length, L_{WL}, is as defined in Pt 3, Ch 1,6.2.

2.1.20 **Protected structure,** *see* Fig. 2.2.3. A protected structure is one in which the wet-deck component under consideration is enclosed by port and starboard side inboard structure, where 'side inboard' is as defined in Ch 4,1.5.6 of Parts 6, 7 and 8 for craft of steel, aluminium alloy and composite construction respectively.

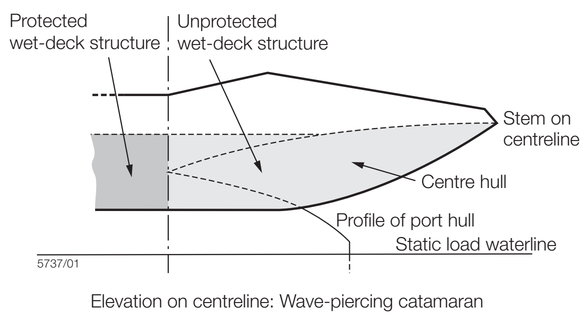


Fig. 2.2.3
Definition of wet-deck protected and unprotected structure

2.1.21 **Unprotected structure,** *see* Fig. 2.2.3. An unprotected structure is one in which the wet-deck component under consideration is not enclosed by port and starboard side inboard structure, where 'side inboard' is as defined in Ch 4,1.5.6 of Parts 6, 7 and 8 for craft of steel, aluminium alloy and composite construction respectively.

2.2 Symbols

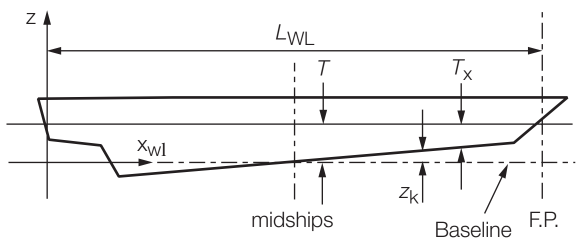
2.2.1 L_R, B, D, C_b, L_{WL} and T are as defined in Pt 3, Ch 1,6.2:

x_{wl} = longitudinal distance, in metres, measured forwards from the aft end of the L_{WL} to the position or centre of gravity of the item being considered

z = vertical distance, in metres, from the baseline to the position of centre of gravity of the item being considered. z is positive above the baseline
Normally the following definitions are to be applied:
z is to be taken at one third of the panel or strake height
For short stiffener members: z is to be taken at the stiffener mid position
For long stiffener members: z is generally to be taken at the stiffener mid position, but may need to be specially considered, especially when there is a significant pressure variation along its length

z_k = vertical distance of the underside of the keel above the baseline, in metres, *see* Fig. 2.2.4

T_x = local draught to operating waterline at longitudinal position under consideration measured above the baseline is to be taken as the horizontal plane passing through the bottom of the moulded hull at midships, *see* Fig. 2.2.4.



NOTE
For any position $T = z_k + T_x$

Fig. 2.2.4 Definition of Symbols

2.2.2 The displacement, Δ, in tonnes, used in this Part is the mass of the craft in the loading condition under consideration.

2.3 Minimum significant wave height

2.3.1 The minimum value of significant wave height, $H_{1/3}$, *see* 2.1.14, in metres, used in the determination of accelerations and loads is, in general, not to be taken less than that given in Table 2.2.1 for the appropriate Service Groups defined in Pt 1, Ch 2,3.5.

2.3.2 The designer/Builder is to provide the value of significant wave height for use in the determination of the Rule loadings and, further, is to ensure that such a wave height is appropriate to the intended area of operation and/or service. In this respect the statistical wave data may be required to be submitted in support of the wave height nominated.

Table 2.2.1 Minimum significant wave height, $H_{1/3}$

Service Group	Minimum significant wave height, in metres
1	0,6
2	1,0
3	2,0
4	4,0
5	4,0
6	4,0

2.3.3 A reduction in the minimum value of significant wave height for a particular Service Group will be specially considered, provided that satisfactory statistical wave data for the intended service area are submitted for approval. *See also* 2.1.14.

■ *Section 3* Motion response

3.1 Relative vertical motion

3.1.1 The relative vertical motion is to be taken as:

$$H_{rm} = C_{w,min}\left(1 + \frac{k_r}{(C_b + 0{,}2)}\left(\frac{x_{wl}}{L_{WL}} - x_m\right)^2\right)$$

where

k_r = *see* Table 2.3.1

$$C_{w,min} = \frac{C_w}{k_m}$$

$$k_m = 1 + \frac{k_r\,(0{,}5 - x_m)^2}{(C_b + 0{,}2)}$$

x_m = $0{,}45 - 0{,}6F_n$ but not less than 0,2
C_w = wave head, in metres
= $0{,}0771 L_{WL}\,(C_b + 0{,}2)^{0{,}3}\ e^{(-0{,}0044 L_{WL})}$
x_{wl} = distance from aft end of L_{WL}, in metres, *see* 2.2.1
L_{WL} = waterline length, in metres, *see* 2.1.19
C_b = block coefficient, *see* 2.2
F_n = Froude Number, *see* 2.1.7, where $V_m = {}^2/_3 V$
V as defined in 2.1.2.

Table 2.3.1 Hull form wave pressure factor

Craft type	k_r
Mono-hull craft in the non-displacement mode	2,25
Mono-hull craft in the displacement mode	1,95
Catamarans and multi-hull craft with partially submerged hulls	2,55
Swaths and multi-hull craft with fully submerged hulls	2,10
Craft supported by hydrodynamic lift provided by foils or other lifting devices	1,50
NOTE Where multiple craft types apply, the higher value of k_r is to be used.	

3.2 Vertical acceleration

3.2.1 The instantaneous accelerations determined in accordance with the formulae in this Section are to be used to estimate the relationship between allowable speed, V, in knots, wave height, $H_{1/3}$, in metres, and displacement, Δ, in tonnes, and they will form the operational envelope which will be issued as an appendix to the Classification Certificate and be incorporated in the Operational Manual of the craft where such a manual is required by the Rules.

3.2.2 Where the Taylor Quotient, Γ, is greater than 10,8, the motion response criteria are to be specially considered.

3.2.3 The vertical acceleration at the LCG (longitudinal centre of gravity), a_v, is defined as the average of the 1/100 highest accelerations at the LCG.

3.2.4 The vertical acceleration in the non-displacement mode for mono-hull craft is to be taken as:

$$a_v = 1{,}5\theta_B L_1 (H_1 + 0{,}084)(5 - 0{,}1\theta_D)\Gamma^2 \times 10^{-3}$$

where

a_v is the vertical acceleration at the LCG in terms of g

g = acceleration due to gravity (9,81 m/sec^2)

$H_1 = \dfrac{H_{1/3}}{B_W}$, but is not to be taken as less than 0,2

$H_{1/3}$ = design significant wave height in metres

B_c = breadth of hull between the chines or bilge tangential points at LCG, as appropriate, in metres

B_W = breadth of hull at the LCG measured at the waterline, in metres

$L_1 = \dfrac{L_{WL} B_c^3}{B_W \Delta}$, but $\dfrac{L_{WL}}{B_W}$ is not to be taken as less than 3

L_{WL} = waterline length, in metres, *see* 2.1.19

θ_D = deadrise angle at the LCG, in degrees, but is not to be taken as greater than 30°

θ_B = running trim angle in degrees, but is not to be taken as less than 3°

Γ = Taylor Quotient, *see* 2.1.17

Δ = displacement, in tonnes, as defined in 2.2.2.

3.2.5 The vertical acceleration in the non-displacement mode for multi-hull craft is to be taken as:

$$a_v = \frac{f_a L_{WL}}{\Delta}(B_M H_{1/3} + 0{,}084 B_M^2)(5 - 0{,}1\theta_D)\Gamma^2 \times 10^{-3}$$

where

a_v is the vertical acceleration at the LCG in terms of g

f_a = hull form acceleration factor
= 2,7 for craft supported mainly by hydrodynamic lift provided by foils or other lifting devices
= 3,6 for Swaths and multi-hull craft with fully submerged hulls
= 4,5 for catamarans and multi-hull craft with partially submerged hulls

B_M = total breadth of hulls or struts at LCG at the waterline, in metres, excluding tunnels

$H_{1/3}$ = design significant wave height, in metres

L_{WL} = waterline length, in metres, *see* 2.1.19

θ_D = deadrise angle at the LCG, in degrees, but is not to be taken as greater than 30°, *see* 2.1.5

Γ = Taylor Quotient, *see* 2.1.17

Δ = displacement, in tonnes

3.2.6 The vertical acceleration in the displacement mode for all craft is to be taken as:

$$a_v = 0{,}2\Gamma + \frac{34}{L_{WL}}$$

where

a_v is the vertical acceleration at the LCG in terms of g

L_{WL} = waterline length, in metres, *see* 2.1.19

Γ = Taylor Quotient, *see* 2.1.17.

3.2.7 The vertical acceleration, a_x, at any given location distance x_a from the AP along the hull may be taken as:

$$a_x = a_v\left(0{,}86 - 0{,}32\frac{x_a}{L_{WL}} + 1{,}76\left(\frac{x_a}{L_{WL}}\right)^2 + \xi_a\right)$$

where

a_v = vertical acceleration at LCG in terms of g, as appropriate

a_x = is the vertical acceleration at a distance x_a from AP on the static load waterline, in terms of g

x_a = distance from aft end of the static load waterline, in metres, to the point at which the vertical acceleration is calculated

x_{LCG} = distance from aft end of the static load waterline, in metres, to the LCG

L_{WL} = waterline length, in metres, *see* 2.1.19

$$\xi_a = 0{,}14 + 0{,}32\frac{x_{LCG}}{L_{WL}} - 1{,}76\left(\frac{x_{LCG}}{L_{WL}}\right)^2$$

■ *Section 4*
Loads on shell envelope

4.1 Pressures on the shell envelope

4.1.1 The design pressures for the shell envelope including exposed decks are to include the effects of combined static and dynamic load components. In addition, the effects of impact or slamming loads are also to be considered, but these are to be treated separately, *see* Section 5.

4.1.2 The individual pressure components are given in 4.3 to 4.5 and the combined pressure to be applied to the shell envelope is given in 4.2. The pressure to be applied to exposed and weather decks is given in 4.5.

4.2 Combined hydrostatic and hydrodynamic pressure on the shell plating

4.2.1 The total pressure distribution, P_s, in kN/m^2 acting on the shell plating envelope due to hydrostatic and hydrodynamic pressures is illustrated in Fig. 2.4.1 and is to be taken as specified in Table 2.4.1.

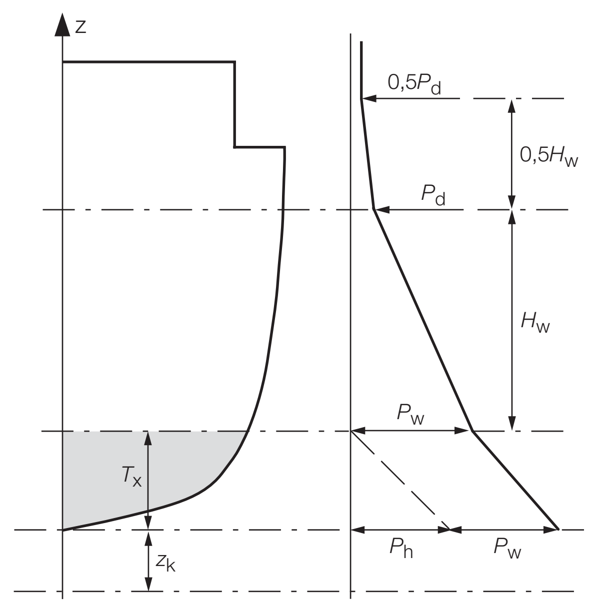


Fig. 2.4.1 Combined pressure distribution, P_s

Table 2.4.1 Combined pressure distribution, P_s

Vertical location i.e. z value	Shell envelope pressure, P_s kN/m^2
For $z \le T_x + z_k$ i.e. up to the operating waterline	$P_h + P_w$
At $z = T_x + z_k + H_w$	P_d
At $z \ge T_x + z_k + 1{,}5H_w$	$0{,}5P_d$
Symbols	
H_w is the nominal wave limit height, *see* 4.4.4 P_d is the weather deck pressure, *see* 4.5.1 P_h is the hydrostatic pressure, *see* 4.3 P_w is the hydrodynamic wave pressure, *see* 4.4 P_h and P_w are to be derived at the appropriate vertical position, z T_x, z and z_k are defined in 2.2	
NOTE Pressure values at other z values are to be derived by interpolation.	

4.3 Hydrostatic pressure on the shell plating

4.3.1 The pressure, P_h, acting on the shell plating up to the operating waterline due to hydrostatic pressure is to be taken as:

$$P_h = 10\,(T_x - (z - z_k))\ \text{kN/m}^2$$

where
T_x, z and z_k are defined in 2.2.

4.4 Hydrodynamic wave pressure

4.4.1 The hydrodynamic wave pressure distribution due to relative motion, P_w, around the shell envelope up to the operating waterline, i.e. $z \le T$, is to be taken as the greater of the following:

P_m kN/m^2 as defined in 4.4.2
P_p kN/m^2 as defined in 4.4.3

4.4.2 The distribution of hydrodynamic pressure up to the operating waterline, P_m, is to be taken as:

$$P_m = 10 f_z H_{rm}\ \text{kN/m}^2$$

where

f_z = the vertical distribution factor

$$= k_z + (1 - k_z)\left(\frac{z - z_k}{T_x}\right)$$

$$k_z = e^{-u}$$

$$u = \left(\frac{2\pi\, T_x}{L_{WL}}\right)$$

H_{rm} is defined in 3.1.1
z, z_k, T_x and L_{WL} are defined in 2.2.

4.4.3 The distribution of hydrodynamic pressure up to the operating waterline, P_p, is to be taken as:

$$P_p = 10 H_{pm}\ \text{kN/m}^2$$

where

$$H_{pm} = 1{,}1\left(\frac{2x_{wl}}{L_{WL}} - 1\right)\sqrt{L_{WL}}$$

but not less than $f_L \sqrt{L_{WL}}$

f_L = 0,6 for $L_{WL} < 60$
= $1{,}5 - 0{,}015L_{WL}$ for $60 \le L_{WL} \le 80$
= 0,3 for $L_{WL} > 80$

L_{WL} = as defined in 2.1.19, but not greater than 150 m
x_{wl} is defined in 3.1.

4.4.4 The nominal wave limit height, H_w, above the design draft, T_x, is to be taken as:

$$H_w = 2H_{rm}\ \text{m}$$

where
H_{rm} is given in 3.1.1.

4.5 Pressure on weather and interior decks

4.5.1 The pressure acting on weather decks, P_d, is to be taken as specified in 4.5.2 or 4.5.3 as applicable.

4.5.2 The pressure acting on weather and interior decks, P_{wh}, in the displacement mode is to be taken as:

$$P_{wh} = f_L (6 + 0{,}01L_{WL}) (1 + 0{,}05\,\Gamma) + E \quad \text{kN/m}^2$$

where

f_L = the location factor for weather decks
= 1,0 from aft end to $0{,}88L_R$
= 1,25 from $0{,}88L_R$ to $0{,}925L_R$
= 1,50 from $0{,}925L_R$ to forward end

f_L = 1,0 for interior decks

$E = \dfrac{0{,}7 + 0{,}08L_{WL}}{D - T}$ kN/m^2 for exposed decks but need not be taken greater than 3 kN/m^2

E = 0,0 for sheltered decks

Γ = Taylor Quotient as defined in 2.1.17

Δ = the displacement as defined in 2.2

L_{WL} is as defined in 2.1.19.

4.5.3 The pressure acting on weather and interior decks, P_{wl}, in the non-displacement mode is to be taken as:

$$P_{wl} = f_L (5 + 0{,}01L_{WL}) (1 + 0{,}5a_v) + E \quad \text{kN/m}^2$$

where f_L and E are as defined in 4.5.2, and a_v is as defined in Section 3.

- a_v is not to be taken less than 1,0, but need not be taken greater than 4,0, for weather decks.
- a_v need not be taken greater than 1,0 for interior decks.

L_{WL} is as defined in 2.1.19.

■ *Section 5* Impact loads

5.1 Impact pressure for displacement mode

5.1.1 The bottom impact pressure, P_{dh}, for mono-hull and multi-hull craft is to be taken as specified in 5.1.2.

5.1.2 The bottom impact pressure due to slamming, P_{dh}, is given by the following expression:

$$P_{dh} = \Phi_{dh}\left(19 - 2720\left(\frac{T_x}{L_{WL}}\right)^2\right)\sqrt{L_{WL}\,V} \quad \text{kN/m}^2$$

$P_{dh} \geq P_m$

Φ_{dh} = 0,09 at L_{WL} from aft end of L_{WL}
= 0,18 at $0{,}9L_{WL}$ from aft end of L_{WL}
= 0,18 at $0{,}8L_{WL}$ from aft end of L_{WL}
= 0,0 between aft end of L_{WL} and $0{,}5L_{WL}$ from aft end of L_{WL}

L_{WL} = waterline length, in metres, *see* 2.1.19

V = allowable speed in knots, *see* 2.1.2.

Intermediate values to be determined by linear interpolation.

T_x is taken to be the draught T, as defined in Pt 3, Ch 1,6, but need not be taken greater than $0{,}08L_{WL}$.

P_{dh} at $0{,}9L_{WL}$ and $0{,}8L_{WL}$ from aft end of L_{WL} need not be taken greater than P_f at L_{WL} from aft end of L_{WL} as defined in 5.4.1.

5.1.3 The side shell impact pressure shall be taken as P_{dh} at the operating waterline, reducing to $0{,}4P_{dh}$ at the weather deck. Intermediate values between the weather deck at side and operating waterline, are to be determined by linear interpolation.

5.2 Impact pressure for non-displacement mode

5.2.1 The impact pressure, P_{dl}, for mono-hull and multi-hull craft is to be taken as specified in 5.2.2 and 5.2.3 as applicable.

5.2.2 The bottom impact pressure due to slamming, P_{dlb}, is given by the following expression:

$$P_{dlb} = \frac{f_d\,\Delta\,\Phi\,(1 + a_v)}{L_{WL}\,G_o} \quad \text{kN/m}^2$$

where

G_o = support girth or girth distance, in metres, as defined in Table 2.5.1

L_{WL} = waterline length, in metres, *see* 2.1.19

a_v = vertical acceleration as defined in 3.2

Δ = displacement, in tonnes, *see* 2.2.2

f_d = hull form pressure factor
= 54 for mono-hull craft
= $\dfrac{81}{N_H}$ for catamarans and multi-hull craft, where

N_H is the number of hulls, but it is not to be taken as greater than four

For craft in continuous contact with water:

Φ = 0,5 at L_{WL} from aft end of L_{WL}
= 1,0 at $0{,}75L_{WL}$ from aft end of L_{WL}
= 1,0 at $0{,}5L_{WL}$ from aft end of L_{WL}
= 0,5 at aft end of L_{WL}

Intermediate values to be determined by linear interpolation.

Otherwise, Φ = 1,0.

Table 2.5.1 Definition of G_o for the determination of bottom impact pressure, P_{dl}, for different regions of the hull

Bottom shell region	G_o	
	Craft with chines	Craft without chines
Between tangential points or chines	G_S	G_S
Between tangential points and design waterline	–	G_{WL}

NOTES
1. G_S = support girth, in metres, as defined in 2.1.15 at LCG.
2. G_{WL} = girth distance, in metres, measured between the waterlines on either side of a hull at the LCG.

5.2.3 The side shell impact pressure for planing craft is to be taken as:

$$P_{\text{dls}} = P_{\text{dlb}} \frac{\tan(40 - \theta_B)}{\tan(\theta_S - 40)} \text{ kN/m}^2\text{, but is not to be taken as greater than } P_{\text{dlb}}$$

where

θ_B = mean deadrise angle of bottom plating, in degrees at local section

θ_S = mean deadrise angle of side plating, in degrees at local section

$(40 - \theta_B)$ is not to be taken as less than 10 degrees

$(\theta_S - 40)$ is not to be taken as less than 10 degrees

P_{dls} is to be taken as constant from the chine or operating waterline to a point half G_o from this point, or the weather deck if this is reached first. Multiple chines will be subject to special consideration based on the above principle. *See* Fig. 2.5.1.

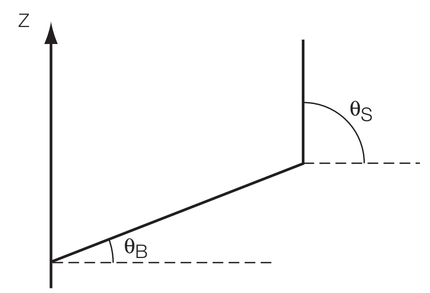


Fig. 2.5.1
Angles used in determination of side shell pressure for planing craft, P_{dls}

Table 2.5.2 Forebody impact pressure factor

Craft type	f_f
Mono-hull craft in non-displacement mode	0,94
Mono-hull craft in displacement mode	0,89
Catamarans and multi-hull craft with partially submerged hulls	1,0
Swaths and multi-hull craft with fully submerged hulls	0,91
Craft supported by hydrodynamic lift provided by foils or other lifting devices	0,81
NOTE Where multiple craft types apply, the higher value of f_f is to be used.	

5.3 Impact pressure for craft with foils and lifting devices

5.3.1 The impact pressure, P_{fb}, for craft supported by hydrodynamic lift provided by foils or other lifting devices is to be taken as specified in 5.3.2 and 5.3.3, as applicable.

5.3.2 The bottom impact pressure, P_{fb}, is given by the greater of P_{fba} or P_{fbb}, where:

$$P_{\text{fba}} = \frac{16}{L_{\text{WL}}} \left(H_{03} + \sqrt{H_0 L_{\text{WL}}}\right)^2 \text{ kN/m}^2$$

$$P_{\text{fbb}} = \frac{1}{3} K_{\text{po}} V_R V \left(1 - \frac{H_0}{H_{03}}\right) \text{ kN/m}^2$$

where

K_{po} = longitudinal distribution factor
= 1,0 between the aft end of the L_{WL} and $0{,}75L_{\text{WL}}$
= 2,0 at L_{WL} from the aft end of L_{WL}, intermediate values to be determined by linear interpolation

H_0 = operational height of craft, in metres, measured from the waterline to the top of the keel at LCG

L_{WL} = waterline length, in metres, *see* 2.1.19

H_{03} = surviving waveheight as defined in 2.1.15 but is not taken as less than 1,0

V = allowable speed, in knots, *see* 2.1.2

P_{fbb} is not taken as less than zero.

V_R is the relative vertical speed of the craft at impact, in knots. If this value is unknown, then the following equation is to be used:

$$V_R = \frac{8H_{1/3}}{\sqrt{L_{\text{WL}}}} + 2 \text{ knots}$$

5.3.3 The side shell impact pressure shall be taken as P_{fb} at the chine or at the operating waterline for round bilge hull-forms, as appropriate, reducing to $0{,}3P_{\text{fb}}$ at the weather deck. Intermediate values between the weather deck at side and the chine or operating waterline, as appropriate, are to be determined by linear interpolation.

5.4 Forebody impact pressure for displacement mode

5.4.1 Forebody and bow slamming pressure, P_f, at the load waterline due to relative motion is to be taken as:

P_f = $f_f L_{\text{WL}} (0{,}8 + 0{,}15\Gamma)^2$ kN/m² at FP

P_f = P_{dh} at $0{,}9L_{\text{WL}}$ from aft end of L_{WL}
= P_m at $0{,}75L_{\text{WL}}$ from aft end of L_{WL}
= 0,0 between aft end of L_{WL} and $0{,}75L_{\text{WL}}$ from aft end of L_{WL}

Intermediate values to be determined by linear interpolation

where

f_f = forebody impact pressure factor as defined in Table 2.5.2

L_{WL} = waterline length, in metres, *see* 2.1.19

Γ = Taylor Quotient, *see* 2.1.17.

5.4.2 The side shell impact pressure shall be taken as P_f at the chine or at the operating waterline for round bilge hull-forms, as appropriate, reducing to 0,4P_f at the weather deck. Intermediate values between the weather deck at side and the chine or operating waterline, as appropriate, are to be determined by linear interpolation.

5.5 Forebody impact pressure for non-displacement mode

5.5.1 Forebody and bow slamming pressure, P_f, at the load waterline due to relative motion is to be taken as:

P_f = the greater of P_{dls} or $f_f L_{WL}$ $(0,8 + 0,15\Gamma)^2$ kN/m^2 at FP
= P_{dls} at 0,75L_{WL} from aft end of L_{WL}
= P_m at 0,5L_{WL} from aft end of L_{WL}
= 0,0 between aft end of L_{WL} and 0,5L_{WL} from aft end of L_{WL}

Intermediate values to be determined by linear interpolation.

where

f_f = forebody impact pressure factor as defined in Table 2.5.2
L_{WL} = waterline length, in metres, *see* 2.1.19
Γ = Taylor Quotient, *see* 2.1.17.

5.5.2 The side shell impact pressure shall be taken as P_f at the chine or at the operating waterline for round bilge hull-forms, as appropriate, reducing to 0,3P_f at the weather deck. Intermediate values between the weather deck at side and the chine or operating waterline, as appropriate, are to be determined by linear interpretation.

■ *Section 6*
Cross-deck structure for multi-hull craft

6.1 Cross-deck structure clearance

6.1.1 For craft with multi-hulls linked by cross-deck structure, sufficient clearance is to be provided between the cross-deck structure and water surface to limit impact loads.

6.1.2 Where part or all of the cross-deck is intended to provide additional buoyancy to limit craft motion, the loading will be specially considered.

6.1.3 In the determination of the clearance, the following factors are to be considered:

(a) Relative motion in waves.
(b) The wave generated between the hulls when running.
(c) The bow sinkage.

6.1.4 The submitted clearance must be validated either by calculations according to accepted theories, model tests, full scale measurements or by documentary evidence if similar structures have proved to be satisfactory in service.

6.1.5 Where it is not possible to provide sufficient clearance to avoid slamming of the cross-deck structure, the equation given in 6.2 is to be used for the assessment of the impact pressures.

6.2 Impact pressure

6.2.1 The impact pressure, P_{pc}, acting on the underside of the cross deck ('wet deck') is to be taken as:

$$P_{pc} = \nabla_{pc} K_{pc} V_R V \left(1 - \frac{G_A}{H_{03}}\right) \text{ kN/m}^2$$

where

K_{pc} = longitudinal distribution factor
= 1,0 between the aft end of the L_{WL} and 0,75L_{WL}
= 2,0 at the L_{WL} from the aft end of L_{WL}, intermediate values to be determined by linear interpolation
G_A = air gap, as defined in 2.1.1
H_{03} = surviving waveheight, as defined in 2.1.16
V = allowable speed, as defined in 2.1.2
∇_{pc} = cross-deck Impact Factor
= 1/6 for protected structures, as defined in 2.1.20
= 1/3 for unprotected structures, as defined in 2.1.21

V_R is the relative vertical speed of the craft at impact, in knots. If this value is unknown, then the following equation is to be used:

$$V_R = \frac{8H_{1/3}}{\sqrt{L_{WL}}} + 2 \text{ knots}$$

■ *Section 7*
Component design loads

7.1 Deckhouses, bulwarks and superstructures

7.1.1 The design pressure, P_{dhp}, for the plating of deck-houses, bulwarks and first tier and above superstructures is given by:

$P_{dhp} = C_1 P_d$ kN/m^2

For structures other than windows:

C_1 = 1,25 for deckhouse and superstructure fronts on upper deck within the forward third of L_R
= 1,15 for deckhouse and superstructure fronts on upper deck outside the forward third of L_R and exposed machinery casings on the upper deck
= 1,0 for deckhouse and superstructure fronts above the lowest tier
= 0,8 for superstructure sides. A value of 0,64 may be used where the sides of the superstructure are stepped in from the sides of the craft by 1,0 m or more
= 0,5 elsewhere
L_R = Rule length in metres, *see* 2.2.1

For windows of toughened safety glass:

$C_1 = W_1 W_2 W_3$

In no case is the design pressure for windows of toughened safety glass to be taken less than $P_{dhp,min}$ as given by:

$P_{dhp,min} = W_1 G_f S_f (10 + 0{,}04 L_{WL})$ kN/m²

where

x_b = distance, in metres, from AP

y = vertical distance, in metres, from the static load waterline at the deepest design draught to the structural element considered

F = $(D – T)$ in metres

L_{WL} = waterline length, in metres, *see* 2.1.19.

W_1 = 2,0 for the lowest tier of unprotected front
= 1,5 for superstructure fronts above the lowest tier
= 1,0 for superstructure sides. A value of 0,8 may be used where the sides of the superstructure are stepped in from the sides of the craft by 1,0 m or more
= 0,67 elsewhere

W_2 = $0{,}67 + 0{,}33 (x_b/L_{WL})$ where $x_b > 0{,}5L_{WL}$ from AP
= 0,67 elsewhere

W_3 = $1 – (y – F)/y$

G_f, S_f and P_d are defined in Chapter 3 or Chapter 4 as appropriate.

D and T are as defined in Pt 3, Ch 1,6.2.

7.2 Watertight and deep tank bulkheads

7.2.1 The design pressure, P_{bh}, on watertight and deep tank bulkheads is to be taken as:

P_{bh} = $11{,}2h_b$ kN/m² for deep tank bulkheads
= $7{,}2h_b$ kN/m² for watertight bulkheads

where

h_b = load head in metres, measured vertically as follows:

(a) Watertight bulkheads
  (i) Plating: the distance from a point one-third of the height of the plate above its lower edge to the bulkhead deck at side.
  (ii) Stiffeners: the distance from mid-point of stiffener span to the bulkhead deck at side.

(b) Deep tank bulkheads
For determination of head, the overflow is to be taken as not less than 1,8 m above the crown of the tank.
  (i) Plating: the greater of:
  - the distance from a point one-third of the height of the plate above its lower edge to the top of the tank
  - half the distance from a point one third of the height of the plate above its lower edge to the top of the overflow.

  (ii) Stiffeners: the greater of:
  - the distance from mid-point of span to the top of the tank
  - half the distance from mid point of span to the top of the overflow.

7.3 Pillars

7.3.1 The design load, P_{PI}, supported by a pillar is to be taken as:

$P_{PI} = S_{gt} b_{gt} P_c + P_a$ kN

where

b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillar, in metres

P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m²

S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

P_{PI} is not to be taken less than 5 kN.

7.4 Deck area designed for cargo, stores and equipment

7.4.1 The cargo deck design pressure, P_{cd}, for plating is to be taken as:

$P_{cd} = W_{CDP} (1 + 0{,}5a_x)$ kN/m²

where a_x is given in Ch 2,3.1.7 and is not to be taken as less than 1,0.

W_{CDP} is the pressure exerted by the cargo on deck specified by the designer in kN/m².

Section 1 General

1.1 Application

1.1.1 The design criteria given in this Chapter are applicable to craft when operating in the non-displacement mode, *see* Ch 1,1.1.

1.1.2 Planing and semi-planing craft are craft with Taylor's Quotient, Γ, as defined in Ch 2,2.1.17, greater than or equal to 3,0.

1.1.3 Light displacement craft are craft with displacement, Δ, in tonnes, less than or equal to $0{,}04(L_R\ B)^{1,5}$, as defined in Pt 1, Ch 2,2.2.10.

1.1.4 The design criteria detailed in this Chapter are to be used in conjunction with the load criteria given in Chapter 2 together with the strength formulae given in Parts 6, 7 and 8 to determine the scantlings of steel, aluminium alloy and composite craft respectively as defined in Part 1.

1.1.5 Alternative methods of establishing the design criteria will be specially considered, provided that they are based on established codes or standards acceptable to LR. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

Section 2 Nomenclature and design factors

2.1 Nomenclature

2.1.1 The nomenclature used in this Chapter is given below:

P_p = pitching pressure, *see* Ch 2,4.4
P_{dl} = bottom impact pressure, *see* Ch 2,5.2
P_{fb} = bottom impact pressure for craft supported by hydrodynamic lift provided by foils or other lifting devices, *see* Ch 2,5.3
P_s = shell envelope pressure, *see* Ch 2,4.2
P_f = forebody impact pressure, *see* Ch 2,5.5
P_{cd} = cargo deck pressure, see Ch 2,7.4
P_{dhp} = deckhouse, bulwarks and superstructure pressure, *see* Ch 2,7.1
P_{bh} = watertight and deep tank bulkhead pressure, *see* Ch 2,7.2
P_{pc} = impact pressure acting on the cross-deck structure, *see* Ch 2,6.2
P_{wl} = pressure on weather deck, *see* Ch 2,4.5
P_{BP} = design pressure for bottom plating
P_{BF} = design pressure for bottom stiffening
P_{SP} = design pressure for side shell plating
P_{SF} = design pressure for side shell stiffening
P_{CP} = design pressure for cross-deck plating
P_{CF} = design pressure for cross-deck stiffening
P_h = hydrostatic pressure, *see* Ch 2,4.3
P_{WDP} = design pressure for weather deck plating
P_{WDF} = design pressure for weather deck stiffening
P_{CRP} = design pressure for coachroof plating
P_{CRF} = design pressure for coachroof stiffening
P_{IDP} = design pressure for interior deck plating
P_{IDF} = design pressure for interior deck stiffening
P_{IBP} = design pressure for inner bottom plating
P_{IBF} = design pressure for inner bottom stiffening
P_{DHP} = design pressure for deckhouse, bulwarks and superstructures plating and windows
P_{DHF} = design pressure for deckhouse, bulwarks and superstructure stiffening
P_{BHP} = design pressure for bulkheads
P_{CDP} = design pressure for cargo deck plating
Δ and Γ are defined in Ch 2,2.2.2 and Ch 2,2.1.17
T, L_R and B are as defined in Pt 3, Ch 1,6.2.

2.1.2 The unit for pressure is kN/m^2.

2.1.3 The design pressure, P, used in the scantling formulae given in Parts 3, 6, 7 and 8 is to be taken as equal to the appropriate value as defined in this Chapter.

2.2 Design factors

2.2.1 The design pressures on structural components are to be calculated taking into consideration the following factors:

(a) Hull notation assigned as defined in Pt 1, Ch 2,3.4.
(b) Service area restriction notation assigned as defined in Pt 1, Ch 2,3.5.
(c) Service type notation assigned as defined in Pt 1, Ch 2,3.6.
(d) Craft type notation assigned as defined in Pt 1, Ch 2,3.7.
(e) Type of stiffening members.

2.2.2 In general, the design pressure, in kN/m^2, for a particular structural component is to be determined as follows:

$$\text{Design pressure} = \delta_f H_f G_f S_f C_f \times \text{load criterion}$$

where

C_f = craft type notation factor given in Table 3.2.4
G_f = service area restriction notation factor given in Table 3.2.2
H_f = hull notation factor given in Table 3.2.1
S_f = service type factor notation given in Table 3.2.3
δ_f = stiffening type factor as given in Table 3.2.5.

Table 3.2.1 Hull notation factor, H_f

Hull notation	Factor
HSC LDC	1,0 0,95
NOTE For a craft eligible for both HSC and LDC notation, the higher value is to be used. H_f is to be taken as 1,0 for a craft not eligible for either the HSC or the LDC notation.	

Table 3.2.2 Service area notation factor, G_f

Service area restriction notation	Factor
G1	0,6
G2	0,75
G3	0,85
G4	1,0
G5	1,2
G6	1,25

Table 3.2.3 Service type notation factor, S_f

Service type notation	Factor
Cargo (A)	1,0
Cargo (B)	1,1
Passenger	1,0
Passenger (A)	1,0
Passenger (B)	1,1
Patrol	1,2
Pilot	1,25
Yacht	1,1
Workboat	1,25

Table 3.2.4 Craft type notation factor, C_f

Craft type notation	Factor
Catamaran	1,0
Hydrofoil	1,1
Mono	1,0
Multi	1,1
RIB	1,15
SES	1,0
SWATH	1,0

Table 3.2.5 Stiffening type factor, δ_f

Type	δ_f
Primary stiffening members and transverse frames	0,5
Secondary and local stiffening members Transverse beams	0,8

■ *Section 3*
Hull envelope design criteria

3.1 Hull structures

3.1.1 The design pressures, in kN/m^2, to be used to determine the scantlings of structural elements are to be taken as specified in Table 3.3.1.

Table 3.3.1 Design pressures for non-displacement craft

Category/location	Craft type	Symbol	Plating pressure	Min.	Symbol	Stiffener pressure	Min.
Mono-hull craft							
Bottom shell	Basic craft	P_{BP}	Greater of $H_f\, S_f\, P_s$ $H_f\, S_f\, C_f\, P_{dl}$ $H_f\, S_f\, G_f\, C_f\, P_f$		P_{BF}	Greater of $\delta_f\, H_f\, S_f\, P_s$ $\delta_f\, H_f\, S_f\, C_f\, P_{dl}$ $\delta_f\, H_f\, S_f\, G_f\, C_f\, P_f$	
	Craft with foils or other lifting devices	P_{BP}	Greater of $H_f\, S_f\, P_s$ $H_f\, S_f\, C_f\, P_{fb}$		P_{BF}	Greater of $\delta_f\, H_f\, S_f\, P_s$ $\delta_f\, H_f\, S_f\, C_f\, P_{fb}$	
Side shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f\, P_{BP}$	
Multi-hull craft							
Bottom shell	Basic craft	P_{BP}	Greater of $H_f\, S_f\, P_s$ $H_f\, S_f\, C_f\, P_{dl}$ $H_f\, S_f\, G_f\, C_f\, P_f$		P_{BF}	Greater of $\delta_f\, H_f\, S_f\, P_s$ $\delta_f\, H_f\, S_f\, C_f\, P_{dl}$ $\delta_f\, H_f\, S_f\, G_f\, C_f\, P_f$	
	Craft with foils or other lifting devices	P_{BP}	Greater of $H_f\, S_f\, P_s$ $H_f\, S_f\, C_f\, P_{fb}$		P_{BF}	Greater of $\delta_f\, H_f\, S_f\, P_s$ $\delta_f\, H_f\, S_f\, C_f\, P_{fb}$	
	Fully submerged hulls	P_{BP}	Greater of $H_f\, S_f\, P_s$ $H_f\, S_f\, G_f\, P_f$		P_{BF}	Greater of $\delta_f\, H_f\, S_f\, P_s$ $\delta_f\, H_f\, S_f\, G_f\, P_f$	
Outboard side shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f\, P_{BP}$	
Inboard side shell		P_{SP}	Greater of P_{BP} 1,6 P_{WDP} at wet deck		P_{SF}	Greater of $\delta_f\, P_{BP}$ 1,9 P_{WDP} at wet deck	
Wet deck		P_{CP}	Greater of $H_f\, S_f\, P_p$ $H_f\, S_f\, P_{pc}$		P_{CF}	Greater of $\delta_f\, H_f\, S_f\, P_p$ $\delta_f\, H_f\, S_f\, P_{pc}$	
Components							
Weather deck (*see* Note 1)		P_{WDP}	Greater of $H_f\, S_f\, G_f\, C_f\, P_{wl}$ P_{cd}	7	P_{WDF}	Greater of $\delta_f\, H_f\, S_f\, G_f\, C_f\, P_{wl}$ P_{cd}	7
Coachroof (*see* Note 1)		P_{CRP}	$H_f\, S_f\, G_f\, C_f\, P_{wl}$	7	P_{CRF}	$\delta_f\, H_f\, S_f\, G_f\, C_f\, P_{wl}$	7
Interior deck		P_{IDP}	Greater of $H_f\, S_f\, C_f\, P_{wl}$ P_{cd}	3,5	P_{IDF}	Greater of $\delta_f\, H_f\, S_f\, C_f\, P_{wl}$ P_{cd}	3,5
Deckhouses, bulwarks and superstructure		P_{DHP}	$H_f\, S_f\, G_f\, C_f\, P_{dhp}$		P_{DHF}	$\delta_f\, H_f\, S_f\, G_f\, C_f\, P_{dhp}$	
Inner bottom		P_{IBP}	$H_f\, S_f\, P_m + P_h$	$10T$	P_{IBF}	$\delta_f\, (H_f\, S_f\, P_m + P_h)$	$10T$
Watertight and deep tank bulkheads		P_{BHP}	P_{bh}		P_{BHF}	P_{bh}	

NOTES
1. G_f is not to be taken less than 1,0.
2. The result of each row in each cell is found as the product of all items on that row in that cell.

■ *Section 1* General

1.1 Application

1.1.1 The design criteria given in this Chapter are applicable to all craft when operating in the displacement mode.

1.1.2 Displacement craft are craft with Taylor's Quotient, Γ, as defined in Ch 2,2.1.17, less than 3,0 and with displacement, Δ, in tonnes, greater than $0{,}04(L_R\ B)^{1{,}5}$, as defined in Ch 2,2.2.2.

1.1.3 The design criteria detailed in this Chapter are to be used in conjunction with the load criteria given in Chapter 2 together with the strength formulae given in Parts 6, 7 and 8 to determine the scantlings of steel, aluminium alloy and composite craft as defined in Part 1.

1.1.4 Alternative methods of establishing the design criteria will be specially considered, provided that they are based on established codes or standards acceptable to LR. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

■ *Section 2* Nomenclature and design factors

2.1 Nomenclature

2.1.1 The nomenclature used in this Chapter is given below:

P_p = pitching pressure, *see* Ch 2,4.4
P_{dh} = bottom impact pressure, *see* Ch 2,5.1
P_{dhp} = deckhouse, bulwarks and superstructure pressure, *see* Ch 2,7.1
P_s = shell envelope pressure, *see* Ch 2,4.1
P_f = forebody impact pressure, *see* Ch 2,5.4
P_{pc} = impact pressure acting on the cross-deck structure, *see* Ch 2,6.2
P_{wh} = pressure on weather deck, *see* Ch 2,4.5
P_{cd} = cargo deck pressure, *see* Ch 2,7.4
P_{bh} = watertight and deep tank bulkhead pressure, *see* Ch 2,7.2
P_{BP} = design pressure for bottom plating
P_{BF} = design pressure for bottom stiffening
P_h = hydrostatic pressure, *see* Ch 2,4.3
P_{SP} = design pressure for side shell plating
P_{SF} = design pressure for side shell stiffening
P_{CP} = design pressure for cross-deck plating
P_{CF} = design pressure for cross-deck stiffening
P_{WDP} = design pressure for weather deck plating
P_{WCDF} = design pressure for weather deck stiffening
P_{CRP} = design pressure for coachroof plating
P_{CRF} = design pressure for coachroof stiffening
P_{IDP} = design pressure for interior deck plating
P_{IDF} = design pressure for interior deck stiffening
P_{IBP} = design pressure for inner bottom plating
P_{IBF} = design pressure for inner bottom stiffening
P_{DHP} = design pressure for deckhouse, bulwarks and superstructures plating and windows
P_{DHF} = design pressure for deckhouse, bulwarks and superstructure stiffening
P_{BHP} = design pressure for bulkheads
P_{CDP} = design pressure for cargo deck plating
Δ and Γ are defined in Ch 2,2.2.2 and Ch 2,2.1.17
T, L_R and B are as defined in Pt 3, Ch 1,6.2.

2.1.2 The unit for pressure is kN/m^2.

2.1.3 The design pressure, P, used in the scantling formulae given in Parts 3, 6, 7 and 8 is to be taken as equal to the appropriate value as defined in this Chapter.

2.2 Design factors

2.2.1 The design pressures on structural components are to be calculated taking into consideration the following factors:

(a) Hull notation assigned as defined in Pt 1, Ch 2,3.4.
(b) Service area restriction notation assigned as defined in Pt 1, Ch 2,3.5.
(c) Service type notation assigned as defined in Pt 1, Ch 2,3.6.
(d) Type of stiffening members.

2.2.2 In general the design pressure, in kN/m^2, for a particular structural component is to be determined as follows:

$$\text{Design pressure} = \delta_f\, H_f\, G_f\, S_f \times \text{load criterion}$$

where

G_f = service area restriction notation factor given in Table 4.2.1
H_f = 1,05
S_f = service type factor notation given in Table 4.2.2
δ_f = stiffening type factor as given in Table 4.2.3.

Table 4.2.1 Service area restriction notation factor, G_f

Service area restriction notation	Factor
G1	0,6
G2	0,75
G3	0,85
G4	1,0
G5	1,2
G6	1,25

Table 4.2.2 Service type notation factor, S_f

Service type notation factor	Factor
Cargo (A)	1,0
Cargo (B)	1,1
Passenger	1,0
Passenger (A)	1,0
Passenger (B)	1,1
Patrol	1,2
Pilot	1,25
Yacht	1,1
Workboat	1,25

Table 4.2.3 Stiffening type factor, δ_f

Type	δ_f
Primary stiffening members and transverse frames	0,5
Secondary and local stiffening members Transverse beams	0,8

■ *Section 3*
Hull envelope design criteria

3.1 Hull structures

3.1.1 The design pressures, in kN/m^2, to be used to determine the scantlings of structural elements are to be taken as specified in Table 4.3.1.

Table 4.3.1 Design pressures for displacement craft

Category/location	Craft type	Symbol	Plating pressure	Min.	Symbol	Stiffener pressure	Min.
Mono-hull craft							
Bottom shell	Basic craft	P_{BP}	Greater of $H_f\,S_f\,P_s$ $H_f\,S_f\,G_f\,P_{dh}$ $H_f\,S_f\,G_f\,P_f$		P_{BF}	Greater of $\delta_f\,H_f\,S_f\,P_s$ $\delta_f\,H_f\,S_f\,G_f\,P_{dh}$ $\delta_f\,H_f\,S_f\,G_f\,P_f$	
Side shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f\,P_{BP}$	
Multi-hull craft							
Bottom shell	Partially submerged hulls	P_{BP}	Greater of $H_f\,S_f\,P_s$ $H_f\,S_f\,G_f\,P_{dh}$ $H_f\,S_f\,G_f\,P_f$		P_{BF}	Greater of $\delta_f\,H_f\,S_f\,P_s$ $\delta_f\,H_f\,S_f\,G_f\,P_{dh}$ $\delta_f\,H_f\,S_f\,G_f\,P_f$	
	Fully submerged hulls	P_{BP}	Greater of $H_f\,S_f\,P_s$ $H_f\,S_f\,G_f\,P_f$		P_{BF}	Greater of $\delta_f\,H_f\,S_f\,P_s$ $\delta_f\,H_f\,S_f\,G_f\,P_f$	
Outboard side shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f\,P_{BP}$	
Inboard side shell		P_{SP}	Greater of P_{BP} 1,6 P_{WDP} at wet deck		P_{SF}	Greater of $\delta_f\,P_{BP}$ 1,9 P_{WDP} at wet deck	
Wet deck		P_{CP}	Greater of $H_f\,S_f\,P_p$ $H_f\,S_f\,P_{pc}$		P_{CF}	Greater of $\delta_f\,H_f\,S_f\,P_p$ $\delta_f\,H_f\,S_f\,P_{pc}$	
Components							
Weather deck (*see* Note 1)		P_{WDP}	Greater of $H_f\,S_f\,G_f\,P_{wl}$ P_{cd}	7	P_{WDF}	Greater of $\delta_f\,H_f\,S_f\,G_f\,P_{wh}$ P_{cd}	7
Coachroof (*see* Note 1)		P_{CRP}	$H_f\,S_f\,G_f\,P_{wl}$	7	P_{CRF}	$\delta_f\,H_f\,S_f\,G_f\,P_{wh}$	7
Interior deck		P_{IDP}	Greater of $H_f\,S_f\,P_{wh}$ P_{cd}	3,5	P_{IDF}	Greater of $\delta_f\,H_f\,S_f\,P_{wh}$ P_{cd}	3,5
Deckhouses, bulwarks and superstructure		P_{DHP}	$H_f\,S_f\,G_f\,P_{dhp}$		P_{DHF}	$\delta_f\,H_f\,S_f\,G_f\,P_{dhp}$	
Inner bottom		P_{IBP}	$H_f\,S_f\,P_m + P_h$	$10T$	P_{IBF}	$\delta_f\,(H_f\,S_f\,P_m + P_h)$	$10T$
Watertight and deep tank bulkheads		P_{BHP}	P_{bh}		P_{BHF}	P_{bh}	

NOTES
1. G_f is not to be taken less than 1,0.
2. The result of each row in each cell is found as the product of all items on that row in that cell.

Section

■ *Section 1* General

1.1 Introduction

1.1.1 The global load and design criteria detailed in this Chapter are to be used in conjunction with Parts 6, 7 and 8 to determine the global hull strength requirements for steel, aluminium alloys and composite craft respectively as defined in Pt 1, Ch 2,2.1.1.

1.1.2 The global load and design criteria given in this Chapter are also provided to enable the designer/Builder to check global hull strength against ductile failure modes involving gross deformation.

1.1.3 The global load criteria are divided into two categories:

(a) Hull girder loads
The types of hull girder loads which are to be considered for strength purposes are distinguished on the basis of their frequencies and they are defined as follows:
  - (i) Still water bending moments and associated shear forces arising from mass distribution and buoyancy forces.
  - (ii) Vertical wave bending moments and associated shear forces arising from low frequency hydrodynamic forces.
  - (iii) Dynamic bending moments and associated shear forces arising from high frequency bottom slamming.

(b) Primary loads for multi-hull craft
These loads arise from the interaction between the hulls and waves.

1.1.4 Alternative methods of establishing the global load and design criteria will be specially considered, provided that they are based on model tests, full scale measurements or other generally accepted theories. In such cases, full details of the methods used and the results are to be provided when plans are submitted for approval.

1.1.5 Longitudinal strength calculations are to be carried out and submitted for approval for craft as required in Parts 6, 7 and 8, as appropriate, covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. The calculations of still water shear forces and bending moments are to cover both departure and arrival conditions and any special mid-voyage conditions caused by changes in ballast distribution.

1.1.6 L_R, B, D, T and C_b are as defined in Pt 3, Ch 1,6.

1.1.7 The vertical acceleration at the LCG, a_v, in terms of g, as defined in Ch 2,3.2, as appropriate, is not to be taken less than 1,0 for the purpose of determining the global load and design criteria.

■ *Section 2* Hull girder load criteria for mono-hull craft

2.1 General

2.1.1 The vertical bending moments specified here are applicable to all mono-hull craft as defined in Pt 1, Ch 2,2.2.12.

2.2 Vertical wave bending moments

2.2.1 For all craft except patrol craft in Service Group G6, the minimum value of vertical wave bending moment, M_W at any position along the craft may be taken as follows:

$M_W = F_f D_f M_o$ kNm

where

F_f = –1,1 for sagging (negative) moment
= $1{,}9C_b/(C_b + 0{,}7)$ for hogging (positive) moment

D_f = the longitudinal distribution factor
= 0 at aft end of L_R
= 1,0 between $0{,}4L_R$ and $0{,}65L_R$
= 0 at forward end of L_R

Intermediate values of D_f are to be determined by linear interpolation

$M_o = 0{,}1L_f\, G_f\, L_R^2\, B\, (C_b + 0{,}7)$ kNm

$L_f = 0{,}0412L_R + 4{,}0$, for $L_R < 90$ m
$= 10{,}75 - (3 - 0{,}01L_R)^{1,5}$, for $L_R \geq 90$ m

G_f = Service group factor, *see* Pt 1, Ch 2,3.5.5
= 0,5 for G1 craft
= 0,6 for G2 craft
= 0,7 for G3 craft
= 0,8 for G4 craft
= 1,0 for G5 and G6 craft (yachts only)

L_R = Rule length, in metres, as defined in Pt 3, Ch 1,6

C_b to be taken not less than 0,60.

2.2.2 For patrol craft in Service Group G6, the minimum value of vertical wave bending moment, M_W, at any position along the ship may be taken as follows:

$M_W = F_f D_f M_o$ kNm

where

F_f is the hogging, F_{fH}, or sagging, F_{fS}, correction factor based on the amount of bow flare, stern flare, length and effective buoyancy of the aft end of the craft above the waterline. F_{fS} is the sagging (negative) moment correction factor and is to be taken as:

$F_{fS} = -1,10 R_A{}^{0,3}$ for values of $R_A \geq 1,0$

$F_{fS} = -1,10$ for values of $R_A < 1,0$

R_A is an area ratio factor, *see* 2.2.3

An area ratio value of 1,0 results in a sagging correction factor of –1,10

F_{fH} is the hogging (positive) moment correction factor and is to be taken as

$F_{fH} \equiv 1,9C_b/(C_b + 0,7)$

D_f = the longitudinal distribution factor
= 0 at aft end of L_R
= 1,0 between $0,4L_R$ and $0,65L_R$
= 0 at forward end of L_R

Intermediate values of D_f are to be determined by linear interpolation

$M_o = 0,1 L_f L_R{}^2 B_{WL} (C_b + 0,7)$ kNm

$L_f = 0,0412L_R + 4,0$, for $L_R < 90$ m
$= 10,75 - (3 - 0,01L_R)^{1,5}$, for $L_R \geq 90$ m

B_{WL} = maximum breadth at the design waterline, in metres

C_b to be taken not less than 0,60.

2.2.3 The area ratio factor, R_A, for the combined stern and bow shape is to be derived as follows:

$$R_A = \frac{30\,(A_{BF} + 0,5A_{SF})}{L_R\,B_{WL}}$$

where

A_{BF} is the bow flare area, in m^2, *see* 2.2.4

A_{SF} is the stern flare area, in m^2, *see* 2.2.5.

2.2.4 The bow flare area, A_{BF}, is illustrated in Fig. 5.2.1 and may be derived as follows:

$A_{BF} = A_{UB} - A_{LB}$ m^2

where

A_{UB} = half the water plane area at a waterline of $T_{C,U}$ of the bow region of the hull forward of $0,8L_R$ from the AP.

A_{LB} = half the water plane area at the design waterline of the bow region of the hull forward of $0,8L_R$ from the AP.

Note the AP is to be taken at the aft end of the Rule length, L_R

The design waterline is to be taken at T, *see* Pt 3, Ch 1.

Alternatively the following formula may be used:

$A_{BF} = 0,05L_R (b_0 + 2b_1 + b_2) + b_0\,a/2$ m^2

where

b_0 = projection of $T_{C,U}$ waterline outboard of the design waterline at the FP, in metres, *see* Fig. 5.2.1

b_1 = projection of $T_{C,U}$ waterline outboard of the design waterline at $0,9L_R$ from the AP, in metres

b_2 = projection of $T_{C,U}$ waterline outboard of the design waterline at $0,8L_R$ from the AP, in metres

a = projection of $T_{C,U}$ waterline forward of the FP, in metres

$T_{C,U}$ is a waterline taken $L_f/2$ m above the design waterline

$T_{C,U} = T + L_f/2$ m

L_f is given in 2.2.2.

For ships with large bow flare angles above the $T_{C,U}$ waterline the bow flare area may need to be specially considered.

2.2.5 The stern flare area, A_{SF}, is illustrated in Fig. 5.2.1 and is to be derived as follows:

$A_{SF} = A_{US} - A_{LS}$ m^2

where

A_{US} = half the water plane area at a waterline of $T_{C,U}$ of the stern region of the hull from aft to $0,2L_R$ forward of the AP

A_{LS} = half the water plane area at a waterline of $T_{C,L}$ of the stern region of the hull from aft to $0,2L_R$ forward of the AP

$T_{C,L}$ is a waterline taken $L_f/2$ m below the design waterline

$T_{C,L} = T - L_f/2$ m

L_f is given in 2.2.2.

For craft with tumblehome in the stern region, the maximum breadth at any waterline less than $T_{C,U}$ is to be used in the calculation of A_{US}. The effects of appendages including bossings are to be ignored in the calculation of A_{LS}.

2.2.6 The sagging correction factor, F_{fS} , in the vertical wave bending moment formulation in 2.2.2 may be derived by direct calculation methods. Appropriate direct calculation methods may include a combination of long term ship motion analysis, non linear ship motion analysis and static balance on a wave crest or trough.

2.3 Still water bending moments

2.3.1 The still water bending moment, M_S, hogging and sagging is the maximum moment calculated from the loading conditions.

2.3.2 Still water bending moments are to be calculated along the craft length. For these calculations, downward loads are to be taken as positive values and are to be integrated in the forward direction from the aft end of L_R. Hogging bending moments are positive.

2.4 Wave shear force

2.4.1 The wave shear force, Q_W, at any position along the craft is given by:

$$Q_W = \frac{3K_f\,M_o}{L_R} \text{ kN}$$

where K_f is to be taken as follows:

(a) Positive shear force:

K_f = 0 at aft end of L_R
= $1,589C_b/(C_b + 0,7)$ between $0,2L_R$ and $0,3L_R$ from aft end of L_R
= 0,7 between $0,4L_R$ and $0,6L_R$ from aft end of L_R
= 1,0 between $0,7L_R$ and $0,85L_R$ from aft end of L_R
= 0 at forward end of L_R

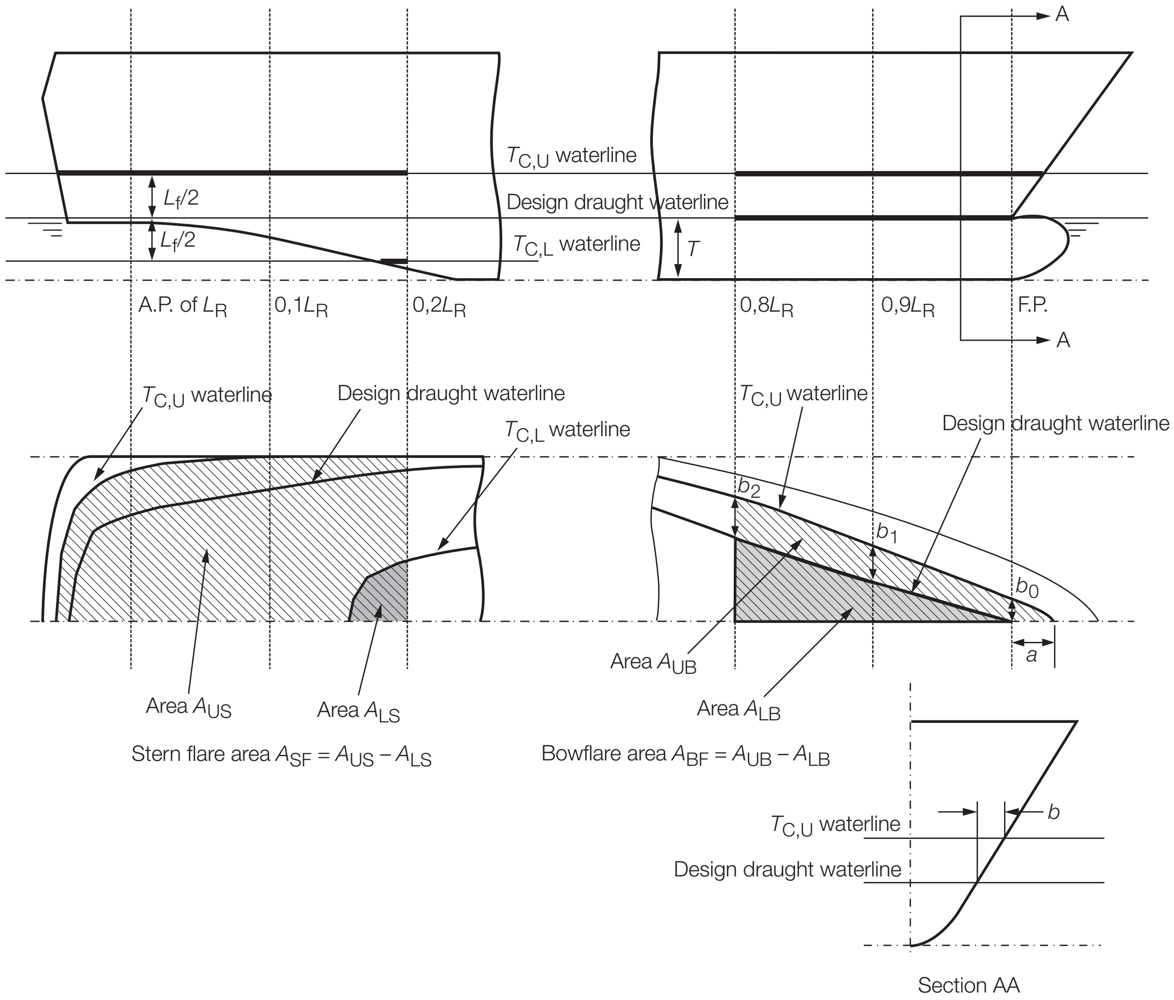


Fig. 5.2.1 Derivation of bow and stern flare areas

(b) Negative shear force:

K_f = 0 at aft end of L_R
= –0,92 between $0,2L_R$ and $0,3L_R$ from aft end of L_R
= –0,7 between $0,4L_R$ and $0,6L_R$ from aft end of L_R
= $-1,727C_b/(C_b + 0,7)$ between $0,7L_R$ and $0,85L_R$ from aft end of L_R
= 0 at forward end of L_R

Intermediate values to be determined by linear interpolation.
M_o, C_b are as defined in 2.2.1 and 2.2.2.

2.5 Still water shear force

2.5.1 The still water shear force, Q_s, at each transverse section along the hull is to be taken as the maximum positive and negative value found from the longitudinal strength calculations.

2.5.2 Still water shear forces are to be calculated at each section along the craft length. For these calculations, downward loads are to be taken as positive values and are to be integrated in a forward direction from the aft end of L_R. The shear force is positive when the algebraic sum of all vertical forces aft of the section is positive.

2.5.3 The actual shear force obtained from the longitudinal strength calculations may be corrected for the effect of local forces at the transverse bulkhead, if applicable.

2.6 Dynamic bending moments and associated shear forces

2.6.1 The dynamic bending moments, including wave and still water effects, specified here are applicable to all non-displacement mono-hull craft as defined in Pt 1, Ch 2,2.2.12.

2.6.2 The dynamic bending moment, due to slamming effects at amidships, is to be calculated using the following expression:

$M_{DW} = F_f D_f |M_D|$ kNm

where

$|M_D|$ is taken to be the absolute value of the function, irrespective of signs
M_D = $51\Delta L_R (16a_v - 4a_b - 17a_s - 5) 10^{-3}$ kNm
Δ = displacement, in tonnes, as defined in Ch 2,2.2.2
F_f = –1,0 for sagging (negative) moment
= 1,0 for hogging (positive) moment
D_f = 0 at aft end of L_R

= 1,0 between $0,4L_R$ and $0,65L_R$ from aft
= 0 at forward end of L_R
a_v = vertical acceleration at the LCG, in terms of g, as defined in Ch 2,3.2.4, *see also* 1.1.6
a_b = vertical acceleration at forward end of L_R, in terms of g
a_s = vertical acceleration at aft end of L_R, in terms of g

If the values of a_b and a_s are unknown, the distributions given in Ch 2,3.2.7 are applicable.

2.6.3 The bottom longitudinal amidships are additionally subjected to the following effective pressure, P_s:

$P_s = 0{,}14P_{dl} + 8T$ kN/m^2

where
P_{dl} is as defined in Ch 2,5.2.1. T is as defined in Pt 3, Ch 1,6.

2.6.4 The bottom plating amidships is subjected to the following additional effective pressure, P_t:

$P_t = 0{,}175P_{dl} + 10T$ kN/m^2

where
P_{dl} is as defined in Ch 2,5.2.1. T is as defined in Pt 3, Ch 1,6.

2.6.5 The dynamic shear force, Q_{DW}, at any position along the craft is given by:

$$Q_{DW} = \frac{4K_f M_D}{L_R} \text{ kN}$$

where M_D is as defined in 2.6.2 and K_f is as defined in 2.4.1.

■ *Section 3* Hull girder load criteria for multi-hull craft

3.1 General

3.1.1 The vertical bending moments specified here are applicable to all multi-hull craft as defined in Pt 1, Ch 2,2.2.13.

3.1.2 L_R and T are as defined in Pt 3, Ch 1,6.

3.2 Vertical wave bending moments and associated shear forces

3.2.1 The vertical wave bending moments, M_{MW}, including wave and still water effects, at amidship is given by the following:

$M_{MW} = F_f D_f M_M$ kNm

where
$M_M = S_f G_f E_f C_{WP} L_S^{2,5} B_M$ kNm
C_{WP} = the waterplane area coefficient and is to be taken not less than 0,5
G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 0,5 for G1 craft
= 0,6 for G2 craft
= 0,7 for G3 craft
= 0,8 for G4 craft
= 1,0 for G5 and G6 craft
S_f = 1,1 for passenger and cargo craft
= 1,15 for craft other than cargo and passenger craft
E_f = 0,125 for sagging moment
= 0,2 for hogging moment
F_f = –1,0 for sagging (negative) moment
= 1,0 for hogging (positive) moment
D_f = 0 at aft end of L_R
= 1,0 between $0,4L_R$ and $0,65L_R$ from aft end of L_R
= 0 at forward end of L_R
B_M = total breadth of hulls or struts at LCG at the waterline, in metres, excluding tunnels
L_S = Rule length, L_R, in metres, for partially submerged hulls
= strut length, in metres, for fully submerged hulls.

3.2.2 The wave shear force, Q_{MW}, at any position along the craft is given by:

$$Q_{MW} = \frac{3K_f M_M}{L_S} \text{ kN}$$

where M_M is as defined in 3.2.1 and K_f is as defined in 2.4.1.

3.3 Dynamic bending moments

3.3.1 The dynamic bending moments, including wave and still water effects, specified here are applicable to all non-displacement multi-hull craft as defined in Pt 1, Ch 2,2.2.13.

3.3.2 The dynamic bending moment, M_{MDW}, due to slamming effects at amidships is to be calculated using the following expression:

$M_{MDW} = F_f D_f M_{MD}$ kNm

where
$M_{MD} = 52\Delta L_S (20\, a_v - 5) \times 10^{-3}$ kNm
F_f = –1,0 for sagging (negative) moment
= 1,0 for hogging (positive) moment
D_f = 0 at aft end of L_R
= 1,0 between $0,4L_R$ and $0,65L_R$ from aft
= 0 at forward end of L_R
a_v = vertical acceleration at the LCG, in terms of g, as defined in Ch 2,3.2.5 as appropriate, *see also* 1.1.6
Δ = displacement, in tonnes, as defined in Ch 2,2.2.2

L_S is as defined in 3.2.1.

3.3.3 The bottom longitudinals amidships are additionally subjected to the following effective pressure, P_s:

$P_s = 0{,}14P_{dl} + 8T$ kN/m^2

where
P_{dl} is as defined in Ch 2,5.2.1. T is as defined in Pt 3, Ch 1,6.

3.3.4 The bottom plating amidships is subjected to the following additional effective pressure, P_t:

$P_t = 0{,}175P_{dl} + 10T$ kN/m^2

where
P_{dl} is as defined in Ch 2,5.2.1. T is as defined in Pt 3, Ch 1,6.

3.3.5 The dynamic shear force, Q_{MDW}, at any position along the craft is given by:

$$Q_{MDW} = \frac{4K_f M_{MD}}{L_S} \text{ kN}$$

where M_{MD} is as defined in 3.3.2. and K_f as defined in 2.4.1.

Section 4 Primary load criteria for multi-hull craft

4.1 General

4.1.1 For multi-hull craft, the strength of the cross deck structure is to be checked for the loadings specified in this Section, *see also* 5.3.

4.1.2 Other values may be used provided they are verified by model experiments, full scale measurements or any other generally accepted theories. Full details are to be submitted for appraisal.

4.1.3 L_R and T are as defined in Pt 3, Ch 1,6.

4.2 Global loads for multi-hull craft with partially submerged hulls

4.2.1 The twin hull transverse bending moment, M_B, about a longitudinal axis is given by:

$M_B = G_f \, b \, \Delta \, a_v$ kNm

where

a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6
b = transverse distance, in metres, between the centre of the two hulls
G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 1,25 for G1 and G2
= 1,50 for G3
= 2,00 for G4
= 2,50 for G5 and G6
Δ = displacement, in tonnes, as defined in Ch 2,2.2.2.

4.2.2 The twin hull torsional connecting moment, M_T, is given by:

$M_T = G_f \, \Delta \, L_R \, a_v$ kNm

where

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 0,63 for G1 and G2
= 0,75 for G3
= 1,00 for G4
= 1,25 for G5 and G6
Δ = displacement, in tonnes, as defined in Ch 2,2.2.2
L_R = Rule length, in metres, as defined in Pt 3, Ch 1,6
a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6.

4.2.3 The vertical shear force, Q_T, at the centreline of the cross-deck structure between the twin hulls is given by:

$Q_T = G_f \, \Delta \, a_v$ kN

where

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 1,25 for G1 and G2
= 1,50 for G3
= 2,00 for G4
= 2,50 for G5 and G6
Δ = displacement, in tonnes, as defined in Ch 2,2.2.2
a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6.

4.3 Global loads for multi-hull craft with fully submerged hulls

4.3.1 The design side force acting at mid-draught of the hull is given by:

$F_{FS} = G_f \, T \, \Delta^{2/3} \, \Psi_1 \, \Psi_2$ kN

where

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 8,5 for G1 and G2
= 10,2 for G3
= 13,6 for G4
= 17,0 for G5 and G6
Δ = displacement, in tonnes, as defined in Ch 2,2.2.2
Ψ_1 = 1,55 – 0,75tanh (Δ/11000)
Ψ_2 = 0,75 + 0,35tanh (1,64$L_S \, \Delta^{-1/3}$ – 6)
L_S = strut length, in metres, at waterline

4.3.2 The lateral pressure acting on the outboard hull may be assumed to be constant and is given by:

$$P_{FS} = \frac{F_{FS}}{A_{FS}} \text{ kN/m}^2$$

where A_{FS} is the projected area, in m^2, of the struts with length L_S at waterline at draught T.

4.3.3 The design transverse bending moment, M_B, due to the side force is given as:

$M_B = F_{FS} (F + 0{,}5T)$ kNm

where F is the distance, in metres, from the waterline to the top of cross structure.

4.3.4 The twin hull torsional connecting moment, M_T, is given by:

$M_T = G_f \, \Delta \, L_R \, a_v$ kNm

where

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 0,63 for G1 and G2
= 0,75 for G3
= 1,00 for G4
= 1,25 for G5 and G6
Δ = displacement, in tonnes, as defined in Ch 2,2.2.2
a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6
L_R = Rule length, in metres, as defined in Pt 3, Ch 1,6

4.3.5 The vertical shear force, Q_T, at the centreline of the cross-deck structure between the twin hulls is given by:

$Q_T = G_f \Delta a_v$ kN

where

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 1,25 for G1 and G2
= 1,50 for G3
= 2,00 for G4
= 2,50 for G5 and G6

Δ = displacement, in tonnes, as defined in Ch 2,2.2.2

a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6.

■ *Section 5* Design criteria and load combinations

5.1 Hull girder design criteria for mono-hull craft

5.1.1 The Rule bending moment, M_R, and associated shear forces, Q_R, for non-displacement craft are to be determined as follows:

(a) The Rule bending moment, M_R, is to be taken as the greater of ($M_w + M_S$), as defined in 2.2 and 2.3 and M_{DW}, as defined in 2.6, taking into account the hogging and sagging conditions.

(b) The Rule shear forces, Q_R, is to be taken as the greater of ($Q_w + Q_S$), as defined in 2.4 and 2.5 and Q_{DW}, as defined in 2.6, taking into account of the hogging and sagging conditions.

5.1.2 The Rule bending moment, M_R, and associated shear forces, Q_R, for displacement craft are taken to be the greater of the following:

(a) The Rule bending moment, M_R, is to be taken as ($M_w + M_S$), as defined in 2.2 and 2.3, taking into account the hogging and sagging conditions.

(b) The Rule shear forces, Q_R, are to be taken as ($Q_w + Q_S$), as defined in 2.4 and 2.5, taking into account the hogging and sagging conditions.

5.1.3 L_R and B are as defined in Pt 3, Ch 1,6. Γ and Δ are defined in Ch 2,2.1.17 and Ch 2,2.2.2 respectively.

5.2 Hull girder design criteria for multi-hull craft

5.2.1 The Rule bending moment, M_R, and associated shear forces, Q_R, for non-displacement craft are to be determined as follows:

(a) The Rule bending moment, M_R, is to be taken as the greater of M_{MW}, as defined in 3.2 and M_{MDW}, as defined in 3.3, taking into account the hogging and sagging conditions.

(b) The Rule shear forces, Q_R, are to be taken as the greater of Q_{MW}, as defined in 3.2 and Q_{MDW}, as defined in 3.3, taking into account the hogging and sagging conditions.

5.2.2 The Rule bending moment, M_R, and associated shear forces, Q_R, for displacement craft are taken to be the greater of the following:

(a) The Rule bending moment, M_R, is to be taken as M_{MW}, as defined in 3.2, taking into account the hogging and sagging conditions.

(b) The Rule shear forces, Q_R, are to be taken as Q_{MW}, as defined in 3.2, taking into account the hogging and sagging conditions.

5.2.3 L_R and B are as defined in Pt 3, Ch 1,6. Γ and Δ are defined in Ch 2,2.1.17 and Ch 2,2.2.2 respectively.

5.3 Primary load combinations applicable to the cross-deck structure of multi-hull craft

5.3.1 If the global load criteria given in this Chapter are utilised to check cross-deck strength against ductile failure modes involving gross deformation, the following load combinations are to be considered depending on heading of the craft:

(a) Head sea
$0,1M_B + M_R + 0,1M_T$

(b) Beam sea
$M_B + 0,1M_R + 0,2M_T$

(c) Quartering sea
$0,1M_B + 0,4M_R + M_T$

M_B, M_T and M_R are to be taken from 4.2.1, 4.2.3 and 5.2 for multi-hull craft with partially submerged hulls.
M_B, M_T and M_R are to be taken from 4.3.1, 4.3.3 and 5.2 for multi-hull craft with fully submerged hulls.

5.3.2 The strength calculations are, in general, to be conducted using the finite element analysis techniques with a three dimensional model.

■ *Section 6* Loading guidance information

6.1 General

6.1.1 Sufficient information is to be supplied to every craft to enable the Master to arrange loading and ballasting in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

6.1.2 This information is to be provided by means of a Loading Manual and in addition, where required, by means of an approved loading instrument.

6.1.3 An Operational manual which contains the craft's assigned operational envelope is to be provided on board, *see* Pt 1, Ch 2,2 and Ch 1,1.

6.2 Loading Manuals

6.2.1 A Loading Manual is to be supplied to all craft where longitudinal strength calculations have been required, *see* Ch 5,1. The Manual is to be submitted for approval in respect of strength aspects. Where both Loading Manual and loading instrument are supplied the Loading Manual must nevertheless be approved from the strength aspect. In this case the Manual is to be endorsed to the effect that any departures from these conditions in service are to be arranged on the basis of the loading instrument and the allowable local loadings shown in the Manual.

6.2.2 The Loading Manual is to be based on the final data of the craft and is to include well-defined lightweight distribution and buoyancy data.

6.2.3 Details of the loading conditions are to be included in the manual as applicable.

6.2.4 The Loading Manual is also to contain the following:

(a) Values of actual and permissible still water bending moments and shear forces and where applicable limitations due to torsional loads.
(b) The allowable local loadings for the structure.
(c) Details of cargo carriage constraints imposed by the use of an accepted coating in association with a system of corrosion control.
(d) A note saying:
'Scantlings approved for minimum draught forward of ...m with ballast tanks No ... filled. In heavy weather conditions the forward draught is not to be less than this value. If, in the opinion of the Master, sea conditions are likely to cause regular slamming, then other appropriate measures such as change in speed, heading or an increase in draught forward may also need to be taken.'

6.2.5 Where alteration to structure, lightweight, cargo distribution or draught is proposed, revised information is to be submitted for approval.

6.3 Loading instrument

6.3.1 In addition to a Loading Manual, an approved type loading instrument is to be provided for craft when it is deemed necessary by LR.

6.3.2 The loading instrument is to be capable of calculating shear forces and bending moments, and where necessary cargo torque, in any load or ballast condition at specified readout points and is to indicate the permissible values. The instrument is to be certified in accordance with Lloyd's Register's (hereinafter referred to as LR) *Approval of Longitudinal Strength and Stability Calculation Programs.*

6.3.3 The instrument readout points are usually selected at the position of the transverse bulkheads or other obvious boundaries. As many readout points as considered necessary by LR are to be included, e.g. between bulkheads.

6.3.4 A notice is to be displayed on the loading instrument stating:

'Scantlings approved for minimum draught forward of ... m with ballast tanks No ... filled. In heavy weather conditions the forward draught is not be to less than this value. If, in the opinion of the Master, sea conditions are likely to cause regular slamming, then other appropriate measures such as change in speed, heading or an increase in draught forward may also need to be taken.'

6.3.5 Where alteration to structure, lightweight or cargo distribution is proposed, the loading instrument is to be modified accordingly and details submitted for approval.

6.3.6 The operation of the loading instrument is to be verified by the Surveyor upon installation and at Annual and Periodical Surveys as required in Pt 1, Ch 3. An Operation Manual for the instrument is to be verified as being available on board.

6.3.7 Where an onboard computer system having a longitudinal strength or a stability computation capability is provided as an Owner's option, it is recommended that the system be certified in accordance with LR's document entitled *Approval of Longitudinal Strength and Stability Calculation Programs.* For systems having a stability computation capability and installed on a new ship, *see also* Pt 1, Ch 2,1.1.10. For systems having a stability computation capability and installed on an existing craft, it is recommended that the system be certified in accordance with LR's document entitled, *Approval of Longitudinal Strength and Stability Calculation Programs.*

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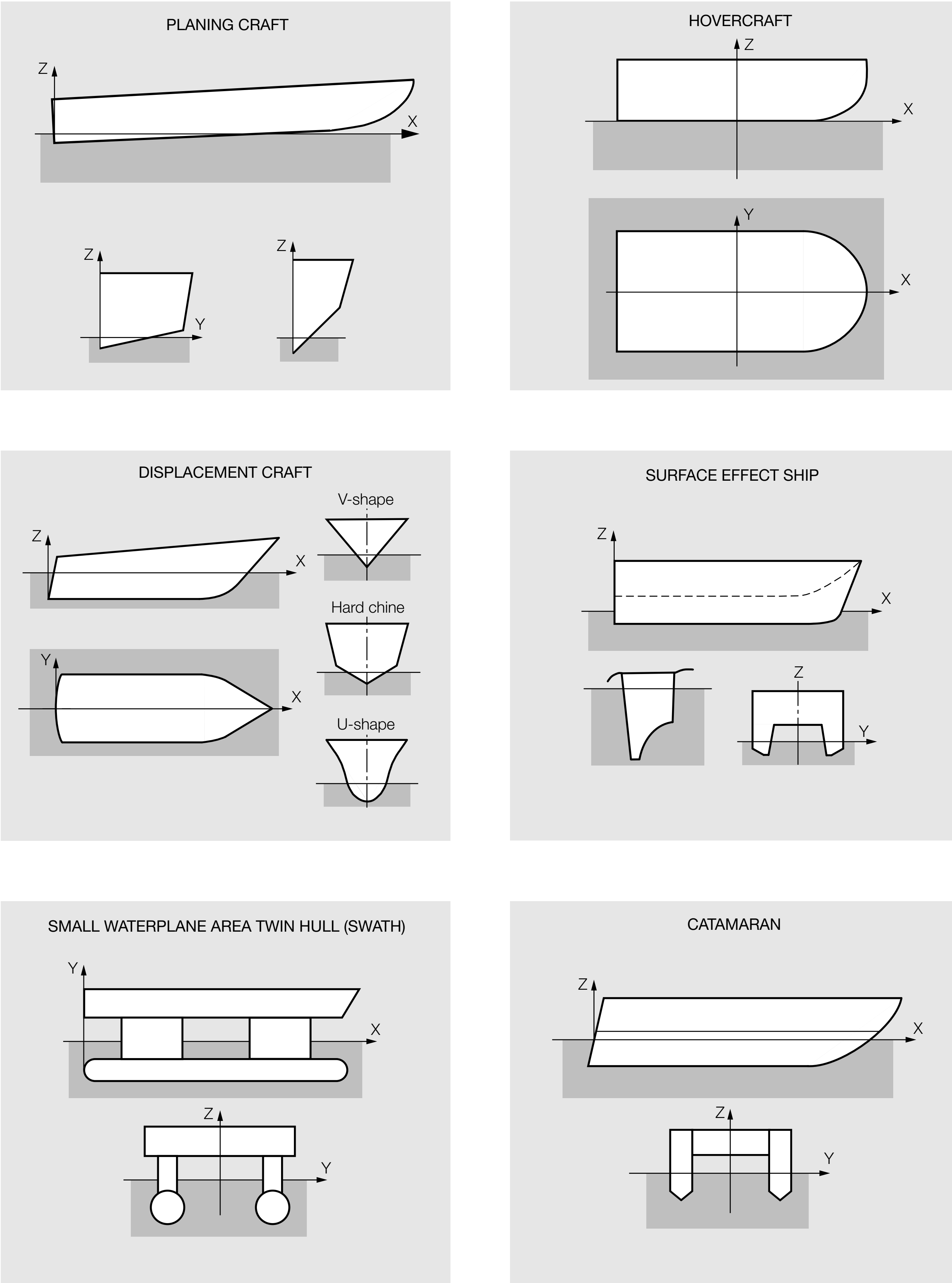
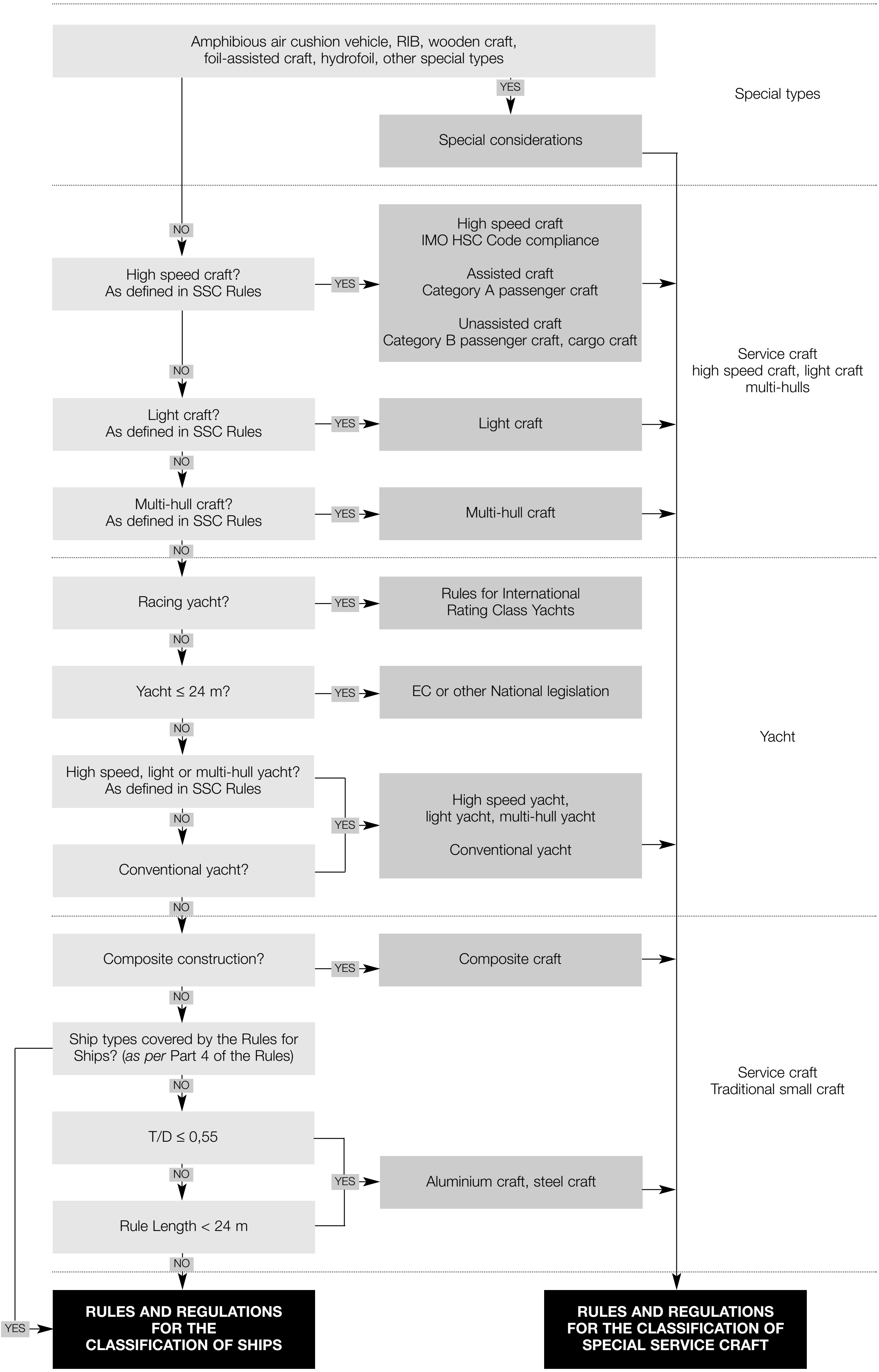
DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES



DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



Chapter Contents

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Section 1 Application

1.1 General

1.1.1 The Rules apply to mono and multi-hull craft of normal form, proportions and speed. Although the Rules are, in general, for steel craft of all welded construction, other materials for use in hull construction will be specially considered on the basis of the Rules.

1.2 Interpretation

1.2.1 The interpretation of the Rules is the sole responsibility and at the sole discretion of Lloyd's Register (hereinafter referred to as 'LR'). Where there is any doubt regarding the interpretation of the Rules it is the Builders' and/or designers' responsibility to obtain clarification from LR prior to submission of plans and data for appraisal.

1.2.2 Where applicable, the Rules take into account unified requirements and interpretations established by the International Association of Classification Societies (IACS).

1.2.3 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside classification as defined in the Rules.

1.3 Equivalents

1.3.1 Alternative scantlings and arrangements may be accepted as equivalent to the Rule requirements. Details of such proposals are to be submitted for consideration in accordance with Pt 3, Ch 1,3.

1.4 Symbols and definitions

1.4.1 The symbols and definitions for use throughout this Part are as defined within the appropriate Chapters and Sections.

Section 2 General requirements

2.1 General

2.1.1 Limitations with regard to the application of these Rules are indicated in the various Chapters for differing craft types.

2.2 Aesthetics

2.2.1 LR is not concerned with the general arrangement, layout and appearance of the craft; the responsibility for such matters remains with the Builders and/or designers to ensure that the agreed specification is complied with. LR is however concerned with the quality of workmanship, in this respect the acceptance criteria as required by Rules are to be complied with.

2.3 Constructional configuration

2.3.1 The Rules provide for the basic structural configurations for both single and multi-deck mono and multi-hull craft with multi-deck or a single deck hulls which include a double bottom, or a single bottom arrangement. The structural configuration may also include a single or multiple arrangement of cargo hatch openings, and side tanks.

2.3.2 The Rules provide for longitudinal and transverse framing systems.

2.3.3 Novel or other types of framing systems will be considered on the basis of the Rules.

2.4 Plans to be submitted

2.4.1 Plans covering the following items are to be submitted:

- Midship sections showing longitudinal and transverse material.
- Profile and decks.
- Shell expansion.
- Oiltight and watertight bulkheads.
- Propeller brackets.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Hatch cover construction.
- Deckhouses and superstructures.
- Sternframe.
- Rudder, stock and tiller.
- Equipment.
- Loading Manuals, preliminary and final (where applicable).
- Scheme of corrosion control (where applicable).
- Ice strengthening.
- Welding schedule.

- Hull penetration plans.
- Support structure for masts, derrick posts or cranes.
- Bilge keels showing material grades, welded connections and detail design.

2.4.2 The following supporting documents are to be submitted:
- General arrangement.
- Capacity plan.
- Lines plan or equivalent.
- Dry-docking plan.
- Towing and mooring arrangements.
- Sail/rigging plan, indicating loadings (as applicable to sailing craft).

2.4.3 The following supporting calculations are to be submitted:
- Equipment Number.
- Hull girder still water and dynamic bending moments and shear forces as applicable.
- Midship section modulus.
- Structural items in the aft end, midship and fore end regions of the craft.
- Preliminary freeboard calculation.

2.5 Novel features

2.5.1 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of LR, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the *Register Book*.

2.6 Enhanced scantlings

2.6.1 Where the Owner decides to increase the scantling of the bottom shell, side shell and deck plating of a newbuilding, then the craft will be eligible to be assigned the description note **ES**, *see* Pt 1, Ch 2,3.12. For example, the descriptive note **ES+1** would indicate that an extra 1 mm of steel has been fitted to bottom shell, side shell and deck plating.

2.7 Direct calculations

2.7.1 Direct calculations may be specifically required by the Rules and may be required for craft having novel design features or in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of designers and make recommendations with regard to suitability of any required model tests.

2.7.2 Where direct calculations are proposed then the requirements of Pt 3, Ch 1,2 are, in general, to be complied with.

2.8 Exceptions

2.8.1 Craft of unusual form, proportions or speed, intended for the carriage of special cargoes, or for special or restricted service, not covered specifically by the Rules, will receive individual consideration based on the general requirements of the Rules.

2.9 Advisory services

2.9.1 The Rules do not cover certain technical characteristics, such as stability, except as mentioned in Pt 1, Ch 2,1.1.11, 1.1.13 and 1.1.14, trim, vibration (other than local stiff end flat panels, *see* Ch 1,5), docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of steel construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 This Chapter contains the general Rule requirements for the construction of steel craft using electric arc welding processes. Where alternative methods of construction are proposed, details are to be submitted for consideration by Lloyd's Register (hereinafter referred to as 'LR').

1.3 Symbols and definitions

1.3.1 The symbols and definitions used in this Chapter are defined in the appropriate Section.

1.4 Builder's facilities

1.4.1 The buildings used for production and storage are to be of suitable construction and equipped to provide the required environment, and are also to comply with any local or National Authority requirements.

1.4.2 The Surveyor is to be allowed unrestricted access during working hours to such parts of the Builder's establishment as may be necessary to ensure that the requirements of the Rules are being complied with.

1.5 Works inspection

1.5.1 Prior to the commencement of construction, the facilities are to be inspected to the satisfaction of the attending Surveyor. This will include the minimum quality control arrangements outlined in 1.6.

1.5.2 The Surveyor is to be satisfied that the Builder has the organisation and capability to construct craft to the standards required by the Rules.

1.5.3 The Builder is to be advised of the result of the inspection and all deficiencies are to be rectified prior to the commencement of production.

1.5.4 Where structural components are to be assembled and welded by sub-contractors, the Surveyors are to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter can be achieved.

1.6 Quality control

1.6.1 For compliance with 1.5.2, LR's methods of survey and inspection for hull construction and machinery installation are to include procedures involving the shipyard management, organisation and quality systems.

1.6.2 The extent and complexity of the quality systems will vary considerably depending on the size and type of craft and production output. LR will consider certification of the Builder in accordance with the requirements of one of the following systems:

(a) Quality Assurance System in accordance with an International or National Standard (i.e. ISO 9000 and BS ENISO 9001) with assessment and certification carried out by a nationally accredited body.
(b) LR's Quality Assurance Scheme for the Construction of Special Service Craft.
(c) LR's locally accepted Quality Control System – The Builder is implementing a documented Quality Control System which controls the following activities:
  (i) Receipt storage and issue of materials, equipment, etc.
  (ii) Fabrication environment.
  (iii) Weld procedures and welder performance.
  (iv) Production fabrication.
  (v) Inspection of production processes.
  (vi) Installation of machinery and essential systems.
  (vii) Fitting-out.
  (viii) Tests and trials.
  (ix) Drawings and document control.
  (x) Records.

1.6.3 LR's involvement is only in that part of the system which controls the standards required to meet the classification requirements.

1.6.4 The 'documented' quality control system will in general require the Builder to have written procedures that describe clearly and unambiguously how each of the activities specified in 1.6.2(c) is carried out, when it is carried out and by whom. These procedures will form part of the system manual which is also to contain a statement of management policy, organisation chart and statements of responsibilities. The manual is to be controlled in respect to the formal issue and revision.

1.6.5 Further details of LR's requirements are available on request from the local LR office.

1.7 Building environment

1.7.1 The craft is to be suitably protected during the building period from adverse weather and climatic conditions.

1.8 Storage areas

1.8.1 All materials are to be stored safely and in accordance with the manufacturer's requirements. Storage arrangements are to be such as to prevent deterioration through contact with heat, sunlight, damp, cold and poor handling.

1.8.2 All storage spaces provided by the Builder for welding consumables are to be suitable for maintaining them in good condition and are to be in accordance with the manufacturer's recommendations.

1.8.3 All materials are to be fully identifiable in the storage areas, and identification is to be maintained during issue to production.

1.8.4 Material suspected of being non-conforming is to be segregated from acceptable materials.

1.9 Materials handling

1.9.1 The Builder is to maintain purchasing documents containing a clear description of the materials ordered for use in hull construction and the standards to which the material must conform, together with the identification and certification requirements.

1.9.2 The Builder is to be responsible for ensuring that all incoming plates, sections, castings, components, fabrications and consumables and other materials used in the hull construction are inspected or otherwise verified as conforming to purchase order requirements.

1.9.3 The Builder is to have procedures for the inspection, storage and maintenance of Owner supplied materials and equipment.

1.9.4 The Builder is to record, on receipt, the manufacturing date, or use-by date of critical materials. Any materials which have a shelf life are to be used in order of manufacturing date to ensure stock rotation.

1.9.5 The Builder is to establish and maintain a procedure to ensure that materials and consumables used in the hull construction process are identified (by colour-coding and/or marking as appropriate) from arrival in the yard through to fabrication in such a way as to enable the type and grade to be readily recognised.

1.9.6 Where materials are found to be defective they are to be rejected in accordance with the Builder's quality control procedure.

1.10 Faults

1.10.1 All identified faults are to be recorded under the requirements of the quality control systems. Faults are to be classified according to their severity and are to be monitored during Periodical Survey.

1.10.2 Production faults are to be discussed with the attending Surveyor and a rectification scheme agreed. Deviations from the approved plans are to be locally approved by the attending Surveyor and a copy forwarded to the plan approval office for record purpose.

1.11 Inspection

1.11.1 On acceptance of a 'Request for Services' the attending Surveyor is to inform the Builder of the key stages of the production that are to be inspected and the extent of the inspection to be carried out.

1.11.2 It is the Builder's responsibility to carry out required inspections in accordance with the accepted quality control system.

1.11.3 It is the Surveyor's responsibility to monitor the Builder's quality control records and carry out inspections at key stages and during periodic visits.

1.11.4 Adequate facilities are to be provided to enable the Surveyor to carry out a satisfactory inspection and to facilitate subsequent in-service maintenance. These are to include the provision of access holes in restricted spaces and removable deck head and shipside linings, cabin soles, etc.

1.11.5 During inspections all deviations are to be dealt with in accordance with 1.6.4.

1.12 Acceptance criteria

1.12.1 Classification is dependent upon the work being carried out in accordance with the approved plans and the requirements of an accepted quality control system.

1.12.2 The work is to be carried out to the satisfaction of the attending Surveyor. This will include the verification of the quality control documentation and the remedial action associated with all defects and deficiencies recorded.

1.12.3 Proposed deviations from the approved plans are subject to LR approval and in the first instance are to be discussed with the attending Surveyor. Where applicable, an amended plan is to be submitted to the plan appraisal office. Such deviations will be recorded as endorsements to the classification unless specifically agreed otherwise with the plan appraisal office.

1.12.4 Where the above requirements are met the attending Surveyor will arrange for the relevant certification to be issued.

1.13 Repair

1.13.1 Minor repairs are to be agreed with the attending Surveyor and a rectification scheme agreed with the Builder. The Builder is to incorporate details of the agreed repair procedures in the quality control system in accordance with 1.6.4.

1.13.2 Repairs which affect the structural integrity are to be discussed with the Builder and the Builder's proposed rectification scheme is to be submitted to the plan appraisal office for consideration.

■ *Section 2* **Materials**

2.1 General

2.1.1 The materials used in the construction of the craft are to be manufactured and tested in accordance with the appropriate requirements of Chapter 3 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.2 All materials are to be manufactured at works which have been approved by LR for the type and, where appropriate, grade of steel which is being supplied and for the relevant steel production and processing route.

2.2 Grade of steel

2.2.1 The grade of steel, supply condition and its mechanical properties are to be indicated on the construction plans.

2.2.2 When plate material, intended for welded construction, will be subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, and tested in accordance with Ch 3,8 of the Rules for Materials.

2.3 Steel castings and forgings

2.3.1 Where steel castings or forgings are used for stern-frames, rudder frames, rudder stocks, propeller shaft brackets and other major structural items, they are to comply with Chapter 4 or Chapter 5, as appropriate.

2.4 Mechanical properties for design

2.4.1 The scantlings determined within this Part of the Rules assume that mild steel has the following mechanical properties:

	N/mm^2
Yield strength (minimum)	235
Tensile strength	400 – 490
Modulus of elasticity	200×10^3

2.4.2 Steel having a specified minimum yield stress of 235 N/mm^2 (24 kgf/mm^2) is regarded as mild steel. Steel having a higher specified minimum yield stress is regarded as higher tensile steel.

2.4.3 The requirements for global strength considerations in craft incorporating higher tensile steel materials are to be based on a material efficiency factor, η_{HTS}, as given in Table 2.2.1.

Table 2.2.1 Values of η_{HTS}

Specified minimum yield stress in N/mm^2	η_{HTS}
235	1,000
265	0,964
315	0,956
340	0,934
355	0,919
390	0,886
NOTE Intermediate values by interpolation.	

2.4.4 The local scantling requirements of higher tensile steel plating, longitudinals, stiffeners and girders may be based on a k_s factor determined as follows:

$$k_s = \frac{235}{\sigma_s}$$

or 0,66 whichever is the greater

where

σ_s = specified minimum yield strength of material, in N/mm^2.

2.4.5 For the application of the requirements of 2.4.3 and 2.4.4 special consideration will be given to steel where $\sigma_s \geq 390$ N/mm^2. Where such steel grades are used in areas which are subject to fatigue loading the structural details are to be verified using fatigue design assessment methods.

2.5 Corrosion protection

2.5.1 All steelwork, except inside integral fuel tanks, is to be suitably protected against corrosion. This may be by coating or, where applicable, by a system of cathodic protection.

2.5.2 Steelwork is to be suitably cleaned and cleared of millscale before the application of any coating. It is recommended that blast cleaning, or other equally effective means, be employed for this purpose.

2.5.3 Where an impressed current cathodic protection system is fitted, plans showing the proposed layout of anodes and hull penetrations are to be submitted.

2.6 Paints and coatings

2.6.1 The hull is to be protected against corrosion by a suitable protective coating. All coatings are to be in accordance with the requirements of this Section.

2.6.2 Where a primer is used to coat steel after surface preparation and prior to fabrication, the composition of the coating is to be such that it will have no significant deleterious effect on subsequent welding work and that it is compatible with the paints or other coatings subsequently applied in association with an approved system of corrosion control.

2.6.3 Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used. Coatings are to be of adequate film thickness, applied in accordance with the paint manufacturer's specification.

2.6.4 Integral fuel tanks are to be cleaned and dried, after testing, and then treated with a suitable coating, in accordance with the manufacturer's recommendations.

2.6.5 Paints, varnishes and similar preparations having a nitro-cellulous or other highly flammable base are not to be used in accommodation or machinery spaces.

2.6.6 Protective coatings are generally to be hard coatings. Other coating systems (e.g. soft coatings) may be considered as alternatives provided they are applied and maintained in compliance with the manufacturer's specification.

2.6.7 The paint or coating is to be compatible with any previously applied primer, *see* 2.6.

2.7 Galvanic action

2.7.1 Where bimetallic connections are made, involving dissimilar metals, measures are to be incorporated to preclude galvanic corrosion. In order to prevent galvanic corrosion, special attention is to be given to the penetrations of, and connections to the hull, bulkheads and decks by piping and, equipment where dissimilar materials are involved.

2.8 Bimetallic connections

2.8.1 The design shall ensure that the location of all bimetallic connections allows for regular inspection and maintenance of the joints and penetrations during service.

2.9 External immersed areas

2.9.1 For the deferment of dry docking or where an **IWS** (In-water Survey) notation is to be assigned protection of the underwater portion of the hull is to be provided by means of a suitable high resistant paint applied in accordance with the manufacturer's requirements. Details of the high resistant paint are to be submitted for information.

2.10 External cathodic protection

2.10.1 Where an impressed current cathodic protection system is fitted, plans showing the proposed layout of anodes, reference cells, wiring diagram and the means of bonding-in of the rudder and propeller, are to be submitted.

2.10.2 The arrangement for glands, where cables pass through the shell, are to include a small cofferdam. Cables to anodes are not to be led through tanks containing low flash point oils.

2.11 Protection of ballast spaces

2.11.1 Cathodic protection may be used in association with coatings for the protection of ballast spaces.

2.11.2 The anodes are to be of approved design and sufficiently rigid to avoid resonance in the anode support. Steel cores are to be fitted, and these are to be so designed as to retain the anode even when the latter is wasted.

2.11.3 Anodes are to be attached to the structure in such a way that they remain secure both initially and during service. The following methods of attachment would be acceptable:

(a) Steel core connected to the structure by continuous welding of adequate section.
(b) Steel core bolted to separate supports, provided that a minimum of two bolts with lock nuts are used at each support. The separate supports are to be connected to the structure by continuous welding of adequate section.
(c) Approved means of mechanical clamping.

2.11.4 Anodes are to be attached to stiffeners, or may be aligned in way of stiffeners on plane bulkhead plating, but they are not to be attached to the shell. The two ends are not to be attached to separate members which are capable of relative movement.

2.11.5 Where cores or supports are welded to the main structure, they are to be kept clear of the toes of brackets and similar stress raisers. Where they are welded to asymmetrical stiffeners, they are to be connected to the web with the welding kept at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the face plate but well clear of the free edges. However, it is recommended that anodes are not fitted to face plates of higher tensile steel longitudinals.

2.12 Deck coverings

2.12.1 Where plated decks are sheathed with wood, the sheathing is to be efficiently attached to the deck, caulked and sealed, to the satisfaction of the Surveyor in accordance with the approved drawings.

2.12.2 Deck coverings in the following positions are to be of a type which will not readily ignite when used on decks:
(a) Forming the crown of machinery or cargo spaces within accommodation spaces of cargo craft.
(b) Within accommodation spaces, control stations, stairways and corridors of passenger craft.

2.13 Corrosion margin

2.13.1 The scantlings determined from the formulae provided in the Rules assume that the materials used are selected, manufactured and protected in such a way that there is negligible loss in strength by corrosion.

2.13.2 Where steel is not protected against corrosion, by painting or other approved means, the scantlings may require to be further considered.

2.14 Fracture control

2.14.1 Construction procedures, materials and welding are to be in accordance with the requirements of this Chapter such that stress corrosion cracking is avoided.

2.14.2 High local stresses are to be avoided by the use of suitable design detail. *See also* LR's *Guidance Notes for Structural Details*.

2.14.3 The resistance to fracture is controlled, in part, by the notch toughness of the steel used in the structure. Steels with different levels of notch toughness are specified in the Rules for Materials. The grade of steel to be used is, in general, related to the thickness of the material and the stress pattern associated with its location.

2.14.4 Where tee or cruciform connections employ full penetration welds, and the plate material is subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, as detailed in Ch 3,8 of the Rules for Materials.

2.14.5 For craft operating for long periods in low air temperature the material of exposed structures will, in general, be specially considered.

■ *Section 3*
Procedures for welded construction

3.1 General

3.1.1 The requirements of this Section are applicable to grades of steel welded using electric arc welding processes. Where it is proposed to use alternative welding processes, details are to be submitted for approval, prior to the start of fabrication.

3.2 Information to be submitted

3.2.1 The plans and information submitted for approval are to clearly indicate details of the welded connections of the main structural members, including the type, disposition and size of welds.

3.3 Welding equipment

3.3.1 Welding plant and appliances are to be suitable for the purpose intended and are to be maintained in an efficient condition. Suitable earthing arrangements are to be provided when welding is being carried out. Satisfactory storage facilities for consumables are to be provided close to working areas.

3.4 Welding consumables

3.4.1 All welding consumables are to be approved by LR and are to be suitable for the type of joint and grade of material, *see* Chapter 11 of the Rules for Materials.

3.4.2 The following grades of consumable are to be used:

For normal strength steels:

Grade 1	For welding Grade A.
Grade 2	For welding any combination of grades other than Grade E to Grade E.
Grade 3	For welding any combination of grades.

For higher tensile steels:

Grade 1Y	For welding Grade AH.
Grade 2Y	For welding any combination of grades other than Grade EH to Grade EH.
Grade 3Y	For welding any combination of grades.

For joints between steels of different grades or different strength levels the welding consumable may be of a type suitable for the lesser grade or strength being connected. The use of a higher grade of welding consumable may be required at discontinuities or other points of stress concentration.

3.4.3 Where the carbon equivalent, calculated from the ladle analysis and using the formula given below, is in excess of 0,45 per cent, approved low hydrogen higher tensile welding consumable and preheating are to be used. Where the carbon equivalent is above 0,41 per cent but is not more than 0,45 per cent approved low hydrogen higher tensile welding consumable are to be used, but preheating will not generally be required except under conditions of high restraint or low ambient temperature. Where the carbon equivalent is not more than 0,41 per cent, any type of approved higher tensile welding consumable may be used and preheating will not generally be required except as above.

$$\text{Carbon equivalent} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

This formula is applicable only to steels which are basically of the carbon-manganese type containing minor quantities of grain refining elements, for example, niobium, vanadium or aluminium. The proposed use of low alloy steels will be subject to special consideration.

3.4.4 Where the structure incorporates mild steel and higher tensile steel, details of the welding arrangements and procedures at the interchange joints are to be submitted for approval in all cases where the chemical analysis of the higher tensile steel requires that it be preheated.

3.4.5 Special care is to be taken in the distribution, storage and handling of all welding consumable. Effective facilities for protecting consumable are to be provided close to working areas.

3.5 Welder qualifications

3.5.1 Welding operators are to be proficient in the type of work on which they are engaged.

3.5.2 The responsibility for selection, training and testing of welding operators rests with the Builders. The Builders are to test welding operators to a suitable National Standard. Records of tests and qualifications are to be kept by the Builders and made available to the Surveyor so that he can be satisfied that the personnel employed during the construction of the craft can achieve the required standard of workmanship.

3.6 Welding procedures

3.6.1 Procedures are to be established for the welding of all joints including the type of consumables, joint preparation and welding position. New procedures will be approved on the basis of a detailed statement of the procedure and process parameters together with the results of examination and testing carried out on sample joints in the presence of the Surveyor. For this purpose, the sample joints are to be prepared under conditions similar to those which will occur during construction of the craft.

3.6.2 The approved arrangements, sequence and procedures are not to be departed from without the prior approval of the Surveyor.

3.6.3 The type and diameter of filler wire, the current, voltage, rate of deposit and number of runs, etc., are to conform to those established in accordance with 3.18. Provision is to be made for checking the above parameters at the welding area.

3.6.4 When required, weld repairs are to be carried out in accordance with the procedures laid down in 3.19.

3.7 Defined practices and welding sequence

3.7.1 Details of the welding procedures, *see* 3.6, and the sequence of welding assemblies and joining up of assemblies are to be submitted.

3.7.2 The proposed sequence of welding is to be agreed with the Surveyor prior to construction.

3.7.3 The type and disposition of connections and sequences of welding are to be so planned that any restraint during welding operations is reduced to a minimum.

3.7.4 Special attention is to be given to the examination of plating in way of all lifting eye plate positions to ensure freedom from cracks. This examination is not restricted to the positions where eye plates have been removed but includes the positions where lifting eye plates are permanent fixtures.

3.7.5 Careful consideration is to be given to assembly sequence and overall shrinkage of plate panels, assemblies, etc., resulting from welding processes employed. Welding is to proceed systematically with each welded joint being completed in correct sequence without undue interruption. Where practicable, welding is to commence at the centre of a joint and proceed outwards or at the centre of an assembly and progress outwards towards the perimeter so that each part has freedom to move in one or more directions. Generally, the welding of stiffener members including transverses, frames, girders, etc., to welded plate panels by automatic processes should be carried out in such a way as to minimise angular distortion of the stiffener.

3.7.6 Butt welds are to be finished full at the ends and cut back before welding the seams. Seams are generally not to be welded within 300 mm of an unwelded butt weld or welded across an unwelded butt joint.

3.7.7 Rudder, sterntubes, propeller brackets and jet units. The final boring out of propeller brackets and sterntubes and the fit-up and alignment of rudder bearings and jet units are to be carried out after the major part of the welding of the aft end of the craft is complete. The contacts between rudder stocks and propeller shafts with bearings are to be checked before the final mounting.

3.7.8 Precautions are to be taken to screen and pre-warm as necessary the general and local weld areas. Surfaces are to be dry.

3.8 Shipyard practices

3.8.1 A sufficient number of skilled supervisors is to be provided to ensure an effective and systematic control at all stages of welding operations.

3.9 Welding environment

3.9.1 Adequate protection is to be provided where welding is required to be carried out in exposed positions in wet, windy or cold weather. In cold weather, precautions should be taken to pre-warm the work and screen where necessary to prevent too rapid cooling of the weld.

3.10 Structural arrangements and access

3.10.1 Ceilings, cabin sole, side and overhead linings are to be secured in such a manner as to be easily removed for the maintenance and inspection of the structure below.

3.10.2 Structural arrangements are to be such as will allow adequate ventilation and access for preheating, where required, and for the satisfactory completion of all welding operations. Welded joints are to be so arranged as to facilitate the use of downhand welding wherever possible.

3.11 Preparation

3.11.1 The preparation of plate edges is to be accurate and essentially free from blemishes. All joints are to be properly aligned and closed or adjusted before welding. Excessive force is not to be used in fairing and closing the work. Means are to be provided for holding the work in proper alignment without rigid restraint during welding operations. Where excessive gaps exist between surfaces or edges to be joined, the corrective measures adopted are to be to the satisfaction of the Surveyor, *see* Pt 3, Ch 1,8.6.

3.11.2 Parts are to be set up and welded in such a way that contraction stresses are kept to a minimum.

3.11.3 Before a manual sealing run is applied to the back of a weld the original root run is to be cut back to sound metal.

3.11.4 Welding is to proceed systematically, each welded joint being completed in proper sequence without undue interruption.

3.11.5 Joint edges are to be scratch brushed (or other acceptable method) immediately before welding in order to remove oxide or adhering films of dirt and filings.

3.12 Cleanliness

3.12.1 The surfaces in way of all parts to be welded are to be clean, dry and free from grease and other contaminants which might adversely affect weld quality. The surfaces and boundaries of each run of deposit are to be thoroughly cleaned and free from slag before the next run is applied.

3.13 Heat treatment

3.13.1 Under conditions of high humidity, the parts to be welded are to be preheated.

3.13.2 Where the parts to be welded are large such that heat conduction prevents the joint from reaching the required temperature, or where the parts to be welded are below 5°C, preheating is to be used.

3.14 Tack welding

3.14.1 Tack welds are to be kept to the minimum and are to be of equal quality to the finished weld. Tack welds which are to be retained as part of the finished weld are to be clean and free from defects before being incorporated into the weld. Care is to be taken when removing tack welds and temporary attachments used for assembly to ensure that the material of the structure is not damaged.

3.14.2 Consumables for tack welding are to be of the same grade as those used for the main weld. Generally, tack welds are not to be applied in lengths of less than 30 mm for mild steel grades and 50 mm for higher tensile steel grades. Care is to be taken to ensure that tack welds, which are to be retained as part of the finished weld, are clean and free from defects before being incorporated. Where tack welds are to be removed, the Surveyors are to ensure that the methods adopted to remove them will not damage the material of the structure.

3.15 Alignment and fit

3.15.1 All joints are to be prepared, aligned and adjusted in accordance with the established joint design. Clamps with wedges or strong-backs used for this purpose are to be suitably arranged to allow freedom of lateral movement between adjacent elements.

3.15.2 Welded temporary attachments used to aid construction are to be removed carefully by grinding, cutting or chipping. The surface of the material is to be finished smooth by grinding followed by crack detection.

3.15.3 Any defects in the structure resulting from the removal of temporary attachments are to be prepared, efficiently welded and ground smooth so as to achieve a defect free repair.

3.16 Inspection

3.16.1 Effective arrangements are to be provided by the Builder for the visual inspection of finished welds in order to ensure that all welding has been satisfactorily completed.

3.17 Testing

3.17.1 Welds are to be clean and free from paint at the time of inspection.

3.17.2 In addition to visual inspection, welded joints are to be examined using any one or a combination of ultrasonic, radiographic, magnetic particle, eddy current, dye penetrant or other acceptable methods appropriate to the configuration of the weld.

3.17.3 The method to be used for the volumetric examinations of welds is the responsibility of the Builder. Radiography is generally to be used on butt welds of 15 mm thickness or less. Ultrasonic testing is acceptable for welds of 15 mm thickness or greater and is to be used for the examination of full penetration tee butt or cruciform welds or joints of similar configuration.

3.17.4 Non-destructive examinations are to be made in accordance with approved written procedures prepared by the Builder, which identify the method and technique to be used, the extent of the examination and the acceptance criteria to be applied.

3.17.5 Non-destructive examinations are to be undertaken by personnel qualified to the appropriate level of a certification scheme recognized by LR.

3.17.6 Checkpoints examined at the pre-fabrication stage are to include ultrasonic testing on examples of the stop/start points of automatic welding and magnetic particle inspections of weld ends.

3.17.7 Checkpoints examined at the construction stage are generally to be selected from those welds intended to be examined as part of the agreed quality control programme to be applied by the Builder. The locations and numbers of checkpoints are to be agreed between the Builder and the Surveyor.

3.17.8 Particular attention is to be paid to highly stressed items. Magnetic particle inspection is to be used at ends of fillet welds, T-joints, joints or crossings in main structural members and at sternframe connections.

3.17.9 Checkpoints for volumetric examination are to be selected so that a representative sample of welding is examined.

3.17.10 Typical locations for volumetric examination and number of checkpoints to be taken are shown in Table 2.3.1. A list of the proposed items to be examined is to be submitted for approval.

3.17.11 For the hull structure of refrigerated spaces and of craft designed to operate in low air temperatures, the extent of non-destructive examination will be specially considered.

3.17.12 For all craft types, the Builder is to carry out random non-destructive examination at the request of the Surveyor.

3.17.13 The full extent of any weld defect is to be ascertained by applying additional non-destructive examinations where required. Unacceptable defects are to be completely removed and where necessary, re-welded. The repair is to be examined after re-welding, *see* 3.19.

3.17.14 Results of non-destructive examinations made during construction are to be recorded and evaluated by the Builder on a continual basis in order that the quality of welding can be monitored. These records are to be made available to the Surveyors.

3.17.15 The extent of applied non-destructive examinations is to be increased when warranted by the analysis of previous results.

Table 2.3.1 Non-destructive examinations of welds

Volumetric non-destructive examinations – Recommended extent of testing, *see* 3.17.10		
Item	Location	Checkpoints, *see* Note 1
Intersections of butts and seams of fabrication and section welds	Throughout: • hull envelope • longitudinal and transverse bulkheads • inner bottom and hopper bottom	The summation of checkpoint lengths, *see* Note 2, examined at intersections is to be *L*, where *L* is the overall length of the ship in metres
Butt welds in plating	Throughout	1 m in 25 m (*see* Note 3)
Seam welds in plating	Throughout	1 m in 100 m
Butts in longitudinals	Hull envelope within 0,4*L* amidships Hull envelope outside 0,4*L* amidships	1 in 10 welds 1 in 20 welds
Bilge keel butts	Throughout	1 in 10 welds
Structural items when made with full penetration welding as follows: • connection of stool and bulkhead to lower stool shelf plating • vertical corrugations to an inner bottom • hopper knuckles • sheerstrake to deck stringer • hatchways coaming to deck	Throughout	1 m in 20 m

NOTES
1. The length of each checkpoint is to be between 0,3 m and 0,5 m.
2. For checkpoints at intersections the measured dimension of length is to be in the direction of the butt weld.
3. Checkpoints in butt welds and seam welds are in addition to those at intersections.
4. Agreed locations are not to be indicated on the blocks prior to the welding taking place, nor is any special treatment to be given at these locations.
5. Particular attention is to be given to repair rates in longitudinal butts. Additional welds are to be tested in the event that defects, such as lack of fusion or incomplete penetrations, are repeatedly observed.

3.18 Acceptance criteria

3.18.1 All finished welds are to be sound and free from cracks and substantially free from lack of fusion, incomplete penetration, porosity and tungsten inclusions. The surfaces of welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and underfill of welds are avoided.

3.18.2 The quality and workmanship of welding of all fittings and attachments to main structure, both permanent and temporary, are to be equivalent to those of the main hull structure.

3.18.3 Visual examination of all welds is to be supplemented by non-destructive examination as considered necessary by the Surveyor.

3.18.4 Fairing, by linear or spot heating, to correct distortions due to welding is, in general, not to be carried out unless procedures have been approved to ensure that the properties of the material are not adversely affected. Visual examination of all heat affected areas and welds in the vicinity is to be carried out to ensure freedom from defects.

3.19 Weld repair

3.19.1 Repairs to defective welding are to be carried out using approved welding consumables and procedures. The repair is to be re-examined for further defects.

3.19.2 Tears and scars left on plating after the removal of temporary lifting lugs, cleats and other temporary fittings or attachments are to be built up by welding if necessary and dressed smooth.

3.19.3 When modifications or repairs have been made which result in openings having to be closed by welded inserts, particular care is to be given to the fit of the insert and the welding sequence. The welding should also be subject to non-destructive testing.

3.19.4 When misalignment of structural members either side of bulkheads, decks, etc., exceeds the agreed tolerance, the misaligned item is to be released, realigned and rewelded in accordance with an approved weld repair procedure, *see also* Pt 3, Ch 1,8.

3.20 Structural detail

3.20.1 Alignment of structure is to be in accordance with 3.15. Triaxial stresses are to be avoided, *see also* LR's *Guidance Notes for Structural Details*.

■ *Section 4* Joints and connections

4.1 General

4.1.1 Requirements are given in this Chapter for welding connection details, aluminium/steel transition joints, steel/wood connection, riveting of light structure and chemical bonding.

4.1.2 Welded joints are to be detailed such that crevices or inaccessible pockets capable of retaining dirt or moisture are avoided. Where cavities are unavoidable, they are to be sealed by welding or protective compounds or made accessible for inspection and maintenance.

4.2 Weld symbols

4.2.1 Weld symbols, where used, are to conform to a recognised National or International Standard. Details of such Standards are to be indicated on the welding schedule, which is to be submitted for appraisal.

4.3 Welding schedule

4.3.1 A welding schedule containing not less than the following information is to be submitted:
(a) Weld throat thickness or leg lengths.
(b) Grades, tempers, and thicknesses of materials to be welded.
(c) Locations, types of joints and angles of abutting members.
(d) Reference to welding procedures to be used.
(e) Sequence of welding of assemblies and joining up of assemblies.

4.4 Butt welds

4.4.1 All structural butt joints are to be made by means of full penetration welds and, in general, the edges of plates to be joined by welding are to be bevelled on one or both sides of the plates. Full details of the proposed joint preparation are to be submitted for approval, *see also* 4.24.

4.4.2 Abrupt change of section is to be avoided where plates of different thicknesses are to be butt welded. Where the difference in thickness exceeds 3 mm, the thicker plate to be welded is to be prepared with a taper not exceeding one in three or with a bevelled edge to form a welded joint proportioned correspondingly. Where the difference in thickness is less than 3 mm the transition may be achieved within the width of the weld. Difference in thickness greater than 3 mm may be accepted provided it can be proven by the Builder, through procedure tests, that the Rule transition shape can be achieved and that the weld profile is such that structural continuity is maintained to the Surveyor's satisfaction.

4.4.3 Where stiffening members are attached by continuous fillet welds and cross completely finished butt or seam welds, these welds are to be made flush in way of the faying surface. Similarly, for butt welds in webs of stiffening members, the butt weld is to be completed and generally made flush with the stiffening member before the fillet weld is made. The ends of the flush portion are to run out smoothly without notches or sudden change of section. Where these conditions cannot be complied with, a scallop is to be arranged in the web of the stiffening member. Scallops are to be of such size, and in such a position, that a satisfactory weld can be made.

4.4.4 Where butt welds form a T-junction, the leg of the T is, where practicable, to be completed first including any back run. During the welding operation special attention is to be given to the completion of the weld at the junction, which is to be chipped back to remove crater cracks, etc., before the table is welded.

4.5 Fillet welds

4.5.1 T-connections are generally to be made by fillet welds on both sides of the abutting plate, the dimensions and spacing of which are shown in Fig. 2.4.1. Where the connection is highly stressed, full penetration welding may be required. Where full penetration welding is required, the abutting plate may need to be bevelled.

4.5.2 The throat thickness of fillet welds is to be determined from:

$$\text{Throat thickness} = t_p \times \text{weld factor} \times \left(\frac{d}{s}\right) \text{ mm}$$

where

s = the length of correctly proportioned weld fillet, clear of end craters, in mm, and is to be 10 x plate thickness, t_p, or 75 mm, whichever is the lesser, but in no case to be taken less than 40 mm

d = the distance between successive weld fillet, in mm

t_p = plate thickness, in mm, on which weld fillet size is based, *see* 4.5.6

Weld factors are contained in Table 2.4.1.

NOTE

For double continuous fillet welding $\left(\frac{d}{s}\right)$ is to be taken as 1 (*see* 4.8.1).

4.5.3 For ease of welding, it is recommended that the ratio of the web height to the flange breadth is greater than or equal to 1,5 (*see* Fig. 2.4.2).

4.5.4 Where an approved automatic deep penetration procedure is used, the weld factors given in Table 2.4.1 may generally be reduced by 15 per cent. Consideration may be given to reductions of up to 20 per cent provided that the Shipyard is able to consistently meet the following requirements:

(a) Suitable process selection confirmed by welding procedure tests covering both minimum and maximum root gaps.

(b) Demonstrate to the satisfaction of the Surveyor, that an established quality control system is in place.

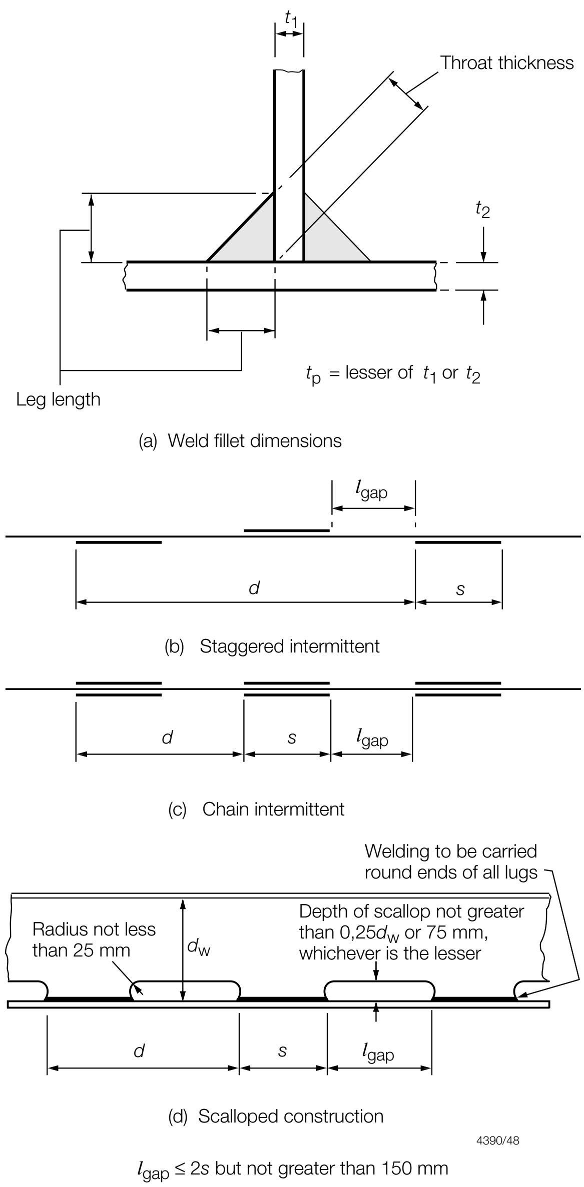


Fig. 2.4.1 Weld types

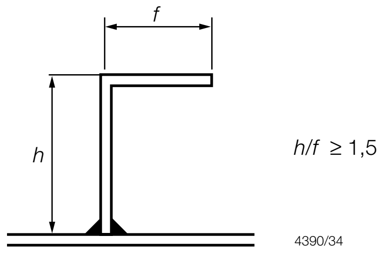


Fig. 2.4.2 Web height/flange breadth ratio

Table 2.4.1 Weld factors (*see continuation*)

Item	Weld Factor	Remarks
(1) General application:		except as required below
Watertight plate boundaries	0,34	
Non-tight plate boundaries	0,13	
Longitudinals,frames,beams, and other secondary members to shell, deck or bulkhead plating	0,10 0,13 0,21	 in tanks in way of end connections
Panel stiffeners	0,10	
Overlap welds generally	0,27	
(2) Bottom construction:		
Non-tight centre girder: to keel to inner bottom	0,27 0,21	 no scallops
Non-tight boundaries of floors, girders and brackets	0,21 0,27	in way of 0,2 x span at ends in way of brackets at lower end of main frame
Inner bottom longitudinals, or face flat to floors reverse frames	0,13	
Connection of floors to inner bottom where bulkhead is supported on tank top. The supporting floors are to be continuously welded to the inner bottom	0,44	Weld size based on floor thickness Weld material compatible with floor material
(3) Hull framing:		
Webs of web frames and stringers: to shell to face plate	 0,16 0,13	
(4) Decks and supporting structure:		
Weather deck plating to shell	0,44	
Other decks to shell and bulkheads (except where forming tank boundaries)	0,21	generally continuous
Webs of cantilevers to deck and to shell in way of root bracket	0,44	
Webs of cantilevers to face plate	0,21	
Girder webs to deck clear of end brackets	0,10	
Girder webs to deck in way of end brackets	0,21	
Web of girder to face plate	0,10	
Pillars: fabricated end connections end connections (tubular)	0,10 0,34 full penetration	
Girder web connections and brackets in way of pillar heads and heels	0,21	continuous

4.5.5 The leg length of the weld is to be not less than $\sqrt{2}$ times the specified throat thickness.

4.5.6 The plate thickness t_p to be used in 4.5.2 is generally to be that of the thinner of the two parts being joined. Where the difference in thickness is considerable, the size of fillet weld will be specially considered.

4.6 Throat thickness limits

4.6.1 The throat thickness limits given in Table 2.4.2 are to be complied with.

Table 2.4.1 Weld factors (*see continuation*)

Item	Weld Factor	Remarks
(5) Bulkheads and tank construction:		
Plane and corrugated watertight bulkhead boundary at bottom , bilge, inner bottom, deck and connection to shelf plate, where fitted	0,44	weld size to be based on thickness of bulkhead plating weld material to be compatible with bulkhead plating material
Secondary members, where acting as pillars	0,13	
Non-watertight pillar bulkhead boundaries	0,13	
Perforated flats and wash bulkhead boundaries	0,10	
Deep tank horizontal boundaries at vertical corrugations	full penetration	
(6) Structure in machinery space:		
Centre girder to keel and inner bottom	0,27	no scallops to inner bottom
Floors to centre girder in way of engine thrust bearers	0,27	
Floors and girders to shell and inner bottom	0,21	
Main engine foundation girders: to top plate to hull structure	deep penetration to depend on design	edge to be prepared with maximum root $0{,}33t_p$ deep penetration generally
Floors to main engine foundation girders	0,27	
Brackets, etc., to main engine foundation girders	0,21	
Transverse and longitudinal framing to shell	0,13	
(7) Superstructures and deckhouses:		
Connection of external bulkheads to deck	0,34 0,21	1st and 2nd tier erections elsewhere
Internal bulkheads	0,13	
(8) Steering control systems:		
Rudder: Fabricated mainpiece and mainpiece to side plates and webs	0,44	
Slot welds inside plates	0,44	
Remaining construction	0,21	
Fixed and steering nozzles: Main structure Elsewhere	0,44 0,21	
Fabricated housing and structure of thruster units, stabilisers, etc.: Main structure Elsewhere	0,44 0,21	

Table 2.4.1 Weld factors (*conclusion*)

Item	Weld Factor	Remarks
(9) Miscellaneous fittings and equipment:		
Rings for manhole type covers, to deck or bulkhead	0,34	
Frames of shell and weathertight bulkhead doors	0,34	
Stiffening of doors	0,21	
Ventilator, air pipes, etc., coamings to deck	0,34 0,21	Load Line Position 1 and 2 elsewhere
Ventilator, etc., fittings	0,21	
Scuppers and discharges, to deck	0,44	
Masts, crane pedestals, etc., to deck	0,44	full penetration welding may be required
Deck machinery seats to deck	0,21	generally
Mooring equipment seats	0,21	generally, but increased or full penetration may be required
Bulwark stays to deck	0,21	
Bulwark attachment to deck	0,34	
Guard rails, stanchions, etc., to deck	0,34	
Bilge keel ground bars to shell	0,34	continuous fillet weld, minimum throat thickness 4 mm
Bilge keels to ground bars	0,21	light continuous or staggered intermittent fillet weld, minimum throat thickness 3 mm
Fabricated anchors	full penetration	

Table 2.4.2 Throat thickness limits

Item	Throat thickness mm	
	Minimum	Maximum
(1) Double continuous welding	$0{,}21t_p$	$0{,}44t_p$
(2) Intermittent welding	$0{,}27t_p$	$0{,}44t_p$ or 4,5
(3) Overriding minimum:		
(a) Continuous welds	2,5	—
(b) Intermittent welds:		
(i) Plate thickness $t_p \leq 7{,}5$ mm		
Hand or automatic welding	3,0	—
Automatic deep penetration welding	3,0	—
(ii) Plate thickness $t_p \geq 7{,}5$ mm Hand or automatic welding	3,25	—
Automatic deep penetration welding	3,0	—

NOTES
1. In all cases the limiting value is to be taken as the greatest of the applicable values above.
2. The maximum throat thicknesses shown are intended only as a design limit for the approval of fillet welded joints. Any welding in excess of these limits is to be to the Surveyor's satisfaction.

4.7 Single sided welding

4.7.1 Where the main welding is carried out from one side only, a back sealing run is to be applied to all butt welds, after suitable back gouging, unless the welding process and consumables have been specially approved for one-side welding.

4.7.2 Where internal access for welding is impracticable, backing bars are to be fitted in way of butt and fillet welds, or alternative means of obtaining full penetration welds are to be agreed. Backing bars may be permanent or temporary.

4.7.3 Permanent backing bars are to be of the same material as the base metal and of thickness not less than the thickness of the plating being joined or 4 mm, whichever is the lesser. The weld is to be thoroughly fused to the backing bar.

4.7.4 Backing bars are to be continuous for the full length of the weld and joints in the backing bar are to be by full penetration welds, ground smooth.

4.7.5 Temporary backing bars for single sided welding may be austenitic stainless steel, glass tape, ceramic, or steel of the same grade as the base metal.

4.7.6 Temporary backing bars are to be suitably grooved in way of the weld to ensure full penetration.

4.8 Double continuous welding

4.8.1 Where double continuous fillet welding is proposed the throat thickness is to be in accordance with 4.5.2 taking $\left(\frac{d}{s}\right)$ equal to 1.

4.8.2 Double continuous welding is to be adopted in the following locations and may be used elsewhere if desired:

(a) Boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings.
(b) Boundaries of tank and watertight compartments.
(c) Main engine seatings.
(d) Bottom framing structure in machinery spaces of high speed craft.
(e) The side and bottom shell structure in the impact area of high speed motor craft.
(f) The underside of the cross-deck structure in the impact area of high speed multi-hull craft.
(g) Structure in way of ride control systems, stabilisers, thrusters, bilge keels, foundations and other areas subject to high stresses.
(h) The shell structure in the vicinity of the propeller blades.
(j) Stiffening members to plating in way of end connections scallops and of end brackets to plating in the case of lap connections.
(k) Primary and secondary members to plating in way of end connections, and end brackets to plating in the case of lap connections.
(l) Face flats to webs of built-up/fabricated stiffening members in way of knees/end brackets and for a distance beyond such knees/end brackets of not less than the web depth of stiffener in way.

4.9 Full penetration welding

4.9.1 Where full penetration welds are required in accordance with 4.4 and 4.5, these are to be made by welding from both sides with the root of the first weld back gouged to sound metal before welding the second side. The weld on the second side may be a sealing run.

4.9.2 Where access to the second side for welding is impracticable, backing bars are to be used in accordance with 4.7.

4.10 Intermittent welding (staggered)

4.10.1 Where intermittent welding is used, the welding is to be made continuous round the ends of brackets, lugs, scallops, etc.

4.10.2 Staggered intermittent welding may be used, outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.11 Intermittent welding (chain)

4.11.1 Chain intermittent welding may be used, outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.12 Slot welding

4.12.1 For the connection of plating to internal webs where access for welding is not practicable, the closing plating is to be attached by continuous full penetration welds, or by slot fillet welds to face plates fitted to the webs. Slots are, in general, to have a minimum length of ten times the plating thickness or 75 mm, whichever is the lesser, but in no case to be taken as less than 40 mm, and a minimum width of twice the plating thickness or 15 mm whichever is the greater, with well rounded ends. Slots cut in plating are to have smooth, clean and square edges and the distance between the slots is, in general, not to exceed 150 mm. Slots are not to be filled with welding. Alternative proposals for length, width and spacing of slot welds will be specially considered.

4.13 Stud welding

4.13.1 Where permanent or temporary studs are to be attached by welding to main structural parts in areas subject to high stress, the proposed location of the studs and the welding procedures adopted are to be to the satisfaction of the Surveyors.

4.14 Lap connections

4.14.1 Overlaps are generally not to be used to connect plates which may be subjected to high tensile or compressive loading and alternative arrangements are to be considered. Where, however, plate overlaps are adopted, the width of the overlap is not, in general to exceed four times nor be less than three times the thickness of the thinner plate and the joints are to be positioned so as to allow adequate access for completion of sound welds. The faying surfaces of lap joints are to be in close contact and both edges of the overlap are to have continuous fillet welds.

4.15 Connections of primary structure

4.15.1 Depending on the structural design of the joint and design loads on the primary member, full penetration welding of flanges and web plates may be required to attain full section properties in the end connections of primary members. *See also* Pt 6, Ch 3,1.22. Otherwise weld factors for the connections of primary structure are given in Table 2.4.1.

4.15.2 The weld connection to shell, deck or bulkhead is to take account of the material lost in the notch where longitudinals or stiffeners pass through the member. Where the width of notch exceeds 15 per cent of the stiffener spacing, the weld factor is to be multiplied by:

$$\frac{0{,}85 \times \text{stiffener spacing}}{\text{length of web plating between notches}}$$

4.15.3 Where direct calculation procedures have been adopted, the weld factors for the 0,2 x overall length at the ends of the members will be considered in relation to the calculated loads.

4.16 Primary and secondary member end connection welds

4.16.1 Welding of end connections of primary members is to be such that the area of welding is not less than the cross-sectional area of the member, and the weld factor is to be not less than 0,34 in tanks or 0,27 elsewhere.

4.16.2 The welding of secondary member end connections is to be not less than as required by Table 2.4.3. Where two requirements are given the greater is to be complied with.

4.16.3 The area of weld, A_w, is to be applied to each arm of the bracket or lapped connection.

4.16.4 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the area of weld is to be not less than the cross-sectional area of the member.

4.17 Weld connection of strength deck plating to sheerstrake

4.17.1 The weld connection of strength deck plating to sheerstrake is to be by double continuous fillet welding with a weld factor of 0,44. The welding procedure, including joint preparation, is to be specified and the procedure qualified and approved for individual Builders.

4.18 Air and drain holes

4.18.1 Air and drain holes are to be kept clear of the toes of brackets, etc. Openings are to be well rounded with smooth edges. *See also* LR's *Guidance Notes for Structural Details*.

4.19 Notches and scallops

4.19.1 Notches and scallops are to be kept clear of the toes of brackets, etc. Openings are to well rounded with smooth edges. Details of scallops are shown in Fig. 2.4.1.

4.19.2 Scallops are to be of such a size, and in such a position that a satisfactory weld can be made around the ends of openings.

4.20 Watertight collars

4.20.1 Watertight collars are to be fitted, where stiffeners are continuous through watertight or oiltight boundaries. *See also* LR's *Guidance Notes for Structural Details*.

Table 2.4.3 Secondary member end connection welds

Connection	Weld area, A_w, in cm^2	Weld factor
(1) Stiffener welded direct to plating	$0{,}25A_s$ or 6,5 cm^2 whichever is the greater	0,34
(2) Bracketless connection of stiffeners or stiffener lapped to bracket or bracket lapped to stiffener:		
(a) in dry space	$1{,}2\sqrt{Z}$	0,27
(b) in tank	$1{,}4\sqrt{Z}$	0,34
(c) main frame to tank side bracket in $0{,}15L_R$ forward	as (a) or (b)	0,34
(3) Bracket welded to face of stiffener and bracket connection to plating	–	0,34
(4) Stiffener to plating for 0,1 x span at ends, or in way of the end bracket if that be greater	–	0,34

Symbols

A_s = cross section area of the stiffener, in cm^2

A_w = the area of the weld, in cm^2, and is calculated as total length of weld, in cm, x throat thickness, in cm

Z = the section modulus, in cm^3, of the stiffener on which the scantlings of the end bracket are based

NOTE
For maximum and minimum weld fillet sizes, *see* Table 10.2.2.

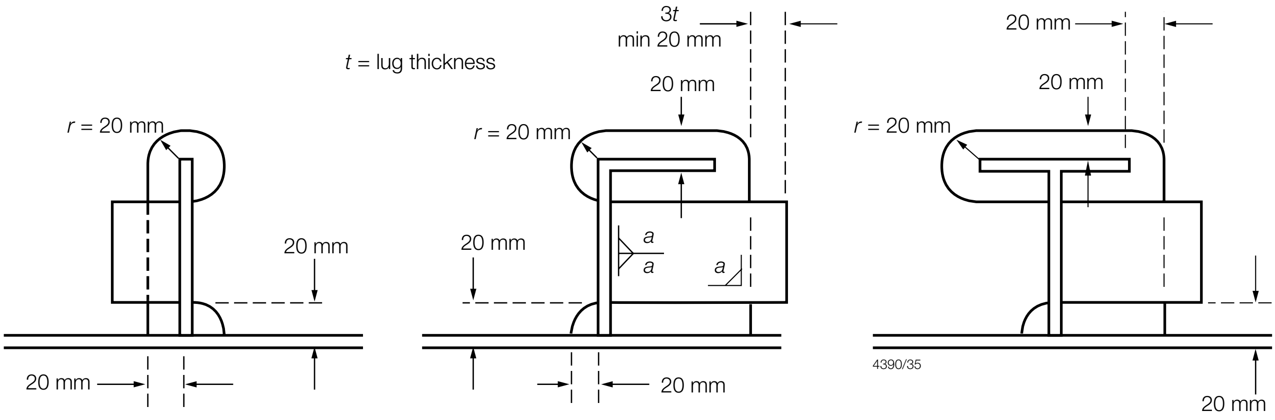


Fig. 2.4.3 Typical lug connections

4.21 Lug connections

4.21.1 The area of the weld connecting secondary stiffeners to primary structure in the bottoms of the hulls and cross-deck structure in areas subjected to impact pressures is to be not less than the shear area from the Rules. This area is to be obtained by fitting two lugs or by other equivalent arrangements. Some typical lug connections are shown in Fig. 2.4.3 and Fig. 3.1.7 in Chapter 3.

4.21.2 Lugs or tripping brackets are to be fitted where shell longitudinals are continuous through web frames in way of highly stressed areas of the side shell (e.g. in way of fenders, etc.).

4.21.3 Lugs or tripping brackets are also to be fitted where continuous secondary stiffeners are greater than half the depth of the primary stiffeners.

4.22 Insert plates

4.22.1 Where thick insert plates are butt welded to thin plates, the edge of the thick plate may require to be tapered. The slope of the taper is generally not to exceed one in three.

4.22.2 The corners of insert plates are to be suitably radiused.

4.23 Doubler plates

4.23.1 Doubler plates are to be avoided in areas where corrosion may be a problem and access for inspection and maintenance is limited.

4.23.2 Where doubler plates are fitted, they are to have well radiused corners and the perimeter is to be continuously welded. Large doubler plates are also to be suitably slot welded, the details of which are to be submitted for consideration.

4.24 Joint preparation

4.24.1 Welded joints are to be prepared in accordance with 3.11. Typical butt joints are shown in LR's *Guidance Notes for Structural Details*.

4.24.2 All other types of joint are to be prepared, aligned and adjusted in accordance with the established joint design. Excessive force is not to be used in fairing and closing the work. The surfaces of parts to be joined are to be accurate, clean, dry and free from blemishes, grease and other contaminants which might adversely affect the joint quality.

4.25 Construction tolerances

4.25.1 The minimum requirements for construction tolerances are to be in accordance with Pt 3, Ch 1,8.

4.26 Riveting of light structure

4.26.1 Where it is proposed to adopt riveted construction, full details of the rivets or similar fastenings, including mechanical test results, are to be indicated on the construction plans submitted for approval or a separate riveting schedule is to be submitted.

4.26.2 Samples may be required of typical riveted joints made by the Builder under representative construction conditions and tested to destruction in the presence of the Surveyor in shear, tension, compression or peel at LR's discretion.

4.26.3 Where riveting strength data sheets have been issued by a recognised Authority, the values quoted in these sheets will normally be accepted for design purposes.

4.26.4 Where two dissimilar metals are to be joined by riveting, precautions are to be taken to eliminate electrolytic corrosion to LR's satisfaction, and where practicable, the arrangements are to be such as to enable the joint to be kept under observation at each survey without undue removal of lining and other items.

4.26.5 Where a sealing compound is used to obtain an airtight or watertight joint, details are to be submitted of its proposed use and of any tests made or experience gained in its use for similar applications.

4.26.6 Sealing paints or compounds are not to be used with hot driven rivets.

4.27 Chemical bonding of structure

4.27.1 Where chemical bonding of any load-bearing structure is proposed, details of the materials and the processes to be used are to be submitted for approval. These details are to include test results of samples manufactured under LR survey under workshop conditions to verify the strength, ageing effects and moisture resistance.

4.27.2 The adhesive manufacturer's recommendations in respect of the specified jointing system, comprising preparation of the surfaces to be adhered, the adhesive, bonding and curing processes, are to be strictly followed as variation of any step can severely affect the performance of the joint.

4.27.3 Meticulous preparation is essential where the joint is to be made by chemical bonding. The method of producing bonded joints is to be documented so that the process is repeatable after the procedure has been properly established.

4.27.4 Bonded joints are suitable for carrying shear loads, but are not, in general, to be used in tension or where the load causes peeling or other forces tending to open the joint. Loads are to be carried over as large an area as possible.

4.27.5 Bonded joints are to be suitably supported after assembly for the period necessary to allow the optimum bond strength of the adhesive to be to be developed. Entrained air pockets are to be avoided.

4.27.6 The use of adhesive for main structural joints is not to be contemplated unless considerable testing has established its validity, including environmental testing and fatigue testing where considered necessary by LR.

4.28 Triaxial stress considerations

4.28.1 Particular care is to be taken to avoid triaxial stresses which may result from poor joint design. Some recommendations in this respect are contained in LR's *Guidance Notes for Structural Details*.

4.29 Aluminium/Steel transition joints

4.29.1 Provision is made in this Section for explosion bonded composite aluminium/steel transition joints used for connecting aluminium structures to steel plating. Such joints are to be used in accordance with the manufacturer's requirements, *see also* Ch 8,4 of the Rules for Materials.

4.29.2 Transition joints are to be manufactured by an approved producer in accordance with an approved specification which is to include the maximum temperature allowable at the interface during welding.

4.29.3 The steel material is to comply with the requirements of Section 2 and the aluminium is to be of an appropriate grade complying with the requirements of Chapter 8 of the Rules for Materials.

4.29.4 Alternative materials which comply with International, National or proprietary specifications may be accepted provided that they give equivalence to the requirements of 4.29.3 or are approved for a specific application.

4.29.5 Intermediate layers between the aluminium and steel may be used, in which case the material of any such layer is to be specified by the manufacturer and is to be recorded in the approval certificate. Any such intermediate layer is then to be used in all production transition joints.

4.29.6 Bimetallic joints where exposed to seawater or used internally within wet spaces are to be suitably protected to prevent galvanic corrosion.

4.30 Steel/Wood connection

4.30.1 To minimise corrosion of steel when in contact with wood in a damp or marine environment the timber is to be primed and painted in accordance with good practice. Alternatively the surface of the steel in contact with the timber is to be coated with a substantial thickness of a suitable sealant.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull craft of steel construction as defined in Pt 1, Ch 2,2.

1.2 General

1.2.1 The formulae contained within this Chapter are to be used in conjunction with the design loadings from Part 5 to determine the Rule scantling requirements.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,3.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

L_R = Rule length of craft, in metres, as defined in Pt 3, Ch 1,6

B = moulded breadth of craft, in metres, as defined in Pt 3, Ch 1,6

Z = section modulus of stiffening member, in cm^3

I = moment of inertia, in cm^4

A_w = shear area of stiffener web, in cm^2

l = stiffener overall length, in metres

l_e = effective span length, in metres, as defined in 1.19

p = design pressure, in kN/m^2 as given in Part 5

s = stiffener spacing, in mm

t_p = plating thickness, in mm

β = panel aspect ratio correction factor as defined in 1.15

γ = convex curvature correction factor as defined in 1.14

k_s = high tensile steel factor
= $235/\sigma_s$, *see also* Ch 2,2.4

σ_s = guaranteed minimum yield strength of the material, in N/mm^2

$\tau_s = \dfrac{\sigma_s}{\sqrt{3}}$

E = modulus of elasticity, in N/mm^2.

1.6 Rounding policy for Rule plating thickness

1.6.1 Where plating thicknesses as determined by the Rules require to be rounded then this should be carried out to the nearest full or half millimetre, with thicknesses 0,75 and 0,25 being rounded up.

1.7 Dimensional tolerance

1.7.1 Dimensional tolerances for materials are to be in accordance with Chapter 8 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), or an acceptable National or International Standard.

1.7.2 The under thickness tolerance acceptable for classification is to be considered as the lower limit of a range of thickness tolerance which could be found in the normal production of a conventional rolling mill manufacturing material, on average, to the nominal thickness.

1.7.3 The Shipowner and Shipbuilder may agree in individual cases whether they wish to specify a more stringent under thickness tolerance than that given in 1.7.2.

1.7.4 The minus tolerance on sections (except for wide flats) is to be in accordance with a National or International Standard.

1.7.5 The thickness of plates and strip is to be measured at random locations whose distance from an edge is to be at least 25 mm. Local surface depressions resulting from imperfections and ground areas resulting from the elimination of defects may be disregarded provided that they are in accordance with the requirements of a National or International Standard.

1.7.6 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer/Builder. Occasional checking by the Surveyor does not absolve the manufacturer/Builder from the responsibility.

1.8 Material properties

1.8.1 The basic grade of steel used in the determination of the Rule scantling requirements is taken as mild steel with the following mechanical properties:

	N/mm^2
Yield strength (minimum)	235
Tensile strength	400 – 490
Modulus of elasticity	200 x 10^3

1.9 Higher tensile steels

1.9.1 Steels having a yield stress not less than 265 N/mm^2 are regarded as higher tensile steels.

1.9.2 Where higher tensile steels are to be used, due allowance is given in the determination of the Rule requirement for plating thickness and stiffener section modulus, inertia and cross-sectional area by use of the following correction factors:

(a) Plating thickness factor = $\sqrt{k_s}$

(b) Section modulus and cross-sectional area factor = k_s

where

k_s is as defined in 1.5.1.

1.9.3 The minimum moment of inertia of higher tensile steel stiffening members is to be not less than that required for mild steel stiffening members.

1.9.4 For determination of hull girder section modulus in craft incorporating higher tensile steel materials, *see* Ch 6,2.2.1, 2.2.2 and Ch 2,2.4.3.

1.10 Effective width of attached plating

1.10.1 The effective geometric properties of rolled or built sections are to be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the actual plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

1.10.2 For stiffening members, the geometric properties of rolled or built sections are to be calculated in association with an effective area of attached load bearing plating of thickness t_p, in mm and a breadth b_e in mm. b_e is as defined in 1.10.3 and 1.10.4.

1.10.3 The effective width of attached plating to secondary members b_e is to be taken as $2t_p\sqrt{E/\sigma_s}$ but not greater than s. σ_s is not to be taken as greater than 235 N/mm^2 for mild steel or 340 N/mm^2 for higher tensile steel. E, s and σ_s are as defined in 1.5.1.

1.10.4 The effective breadth of attached plating to primary support members (girders, transverses, webs etc.) b_e is to be taken as bf, where b and f are as defined in Pt 3, Ch 2, 3.2.1.

1.11 Other materials

1.11.1 Special consideration will be given to the use of materials other than steel. Details of the type of material, the specification to which it was manufactured and its mechanical properties are to be submitted for appraisal.

1.12 Aluminium alloys

1.12.1 The use of aluminium alloys in construction is to be in accordance with Part 7.

1.13 Fibre reinforced plastic (FRP)

1.13.1 The use of FRP in construction is to be in accordance with Part 8.

1.14 Convex curvature correction

1.14.1 The thickness of plating as determined by the Rules may be reduced where significant curvature exists between the supporting members. In such cases a plate curvature correction factor may be applied:

γ = plate curvature factor
= $1 - h/s$, and is not to be taken as less than 0,7,

h = the distance, in mm, measured perpendicularly from the chord length, s, (i.e. spacing) to the highest point of the curved plating arc between the two supports, *see* Fig. 3.1.1.

1.15 Aspect ratio correction

1.15.1 The thickness of plating as determined by the Rules may be reduced when the panel aspect ratio is taken into consideration. In such cases a panel aspect ratio correction factor may be applied:

β = aspect ratio correction factor
= $A_R (1 - 0{,}25A_R)$ for $A_R \leq 2$
= 1 for $A_R > 2$

A_R = panel aspect ratio
= panel length/panel breadth.

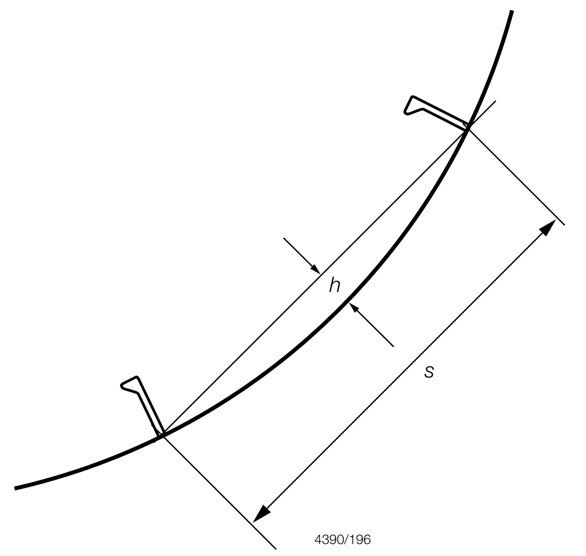


Fig. 3.1.1 Convex curvature

1.16 Plating general

1.16.1 The requirements for the thickness of plating, t_p, is, in general, to be in accordance with the following:

$$t_p = 22{,}4\, s\, \gamma\, \beta \sqrt{\frac{p}{f_\sigma\, \sigma_s}} \times 10^{-3} \text{ mm}$$

where

f_σ = limiting bending stress coefficient for the plating element under consideration given in Table 7.3.1 in Chapter 7.

s, γ, β, p, σ_s are as defined in 1.5.1.

1.17 Stiffening general

1.17.1 The requirements for section modulus, inertia and web area of stiffening members are, in general, to be in accordance with the following:

(a) Section modulus:

$$Z = \Phi_Z \frac{p\, s\, l_e^2}{f_\sigma\, \sigma_s} \text{ cm}^3$$

where

Φ_Z = section modulus coefficient dependent on the loading model assumption taken from Table 3.1.1

f_σ = limiting bending stress coefficient for stiffening member given in Table 7.3.1 in Chapter 7.

p, s, l_e, and σ_s are as defined in 1.5.1.

(b) Inertia:

$$I = \Phi_I\, f_\delta \frac{p\, s\, l_e^3}{E} \times 100 \text{ cm}^4$$

where

Φ_I = inertia coefficient dependent on the loading model assumption taken from Table 3.1.1

f_δ = limiting deflection coefficient for stiffener member given in Table 7.2.1 in Chapter 7.

p, s, l_e, and E are as defined in 1.5.1.

(c) Web area:

$$A_w = \Phi_A \frac{p\, s\, l_e}{100\, f_\tau\, \tau_s} \text{ cm}^2$$

where

Φ_A = web area coefficient dependent on the loading model assumption taken from Table 3.1.1

f_τ = limiting shear stress coefficient for stiffener member given in Table 7.3.1 in Chapter 7

p, s, l_e, and τ_s are as defined in 1.5.1.

1.18 Geometric properties and proportions of stiffener sections

1.18.1 From structural stability and local buckling considerations, the proportions of stiffening members are, in general, to be in accordance with Table 3.1.2.

1.19 Determination of span point

1.19.1 The effective span length, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined as follows:

(a) For rolled or built-up secondary stiffening members: The span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member, is equal to the depth of the member, *see* Fig. 3.1.2. Where there is no end bracket, the span point is to be measured between primary member webs.

(b) For primary support members: The span point is to be taken at a point distant, b_e, from the end of the member

$$b_e = b_b \left(1 - \frac{d_w}{d_b}\right)$$

where

b_e, b_b, d_w and d_b are as shown in Fig. 3.1.2.

1.19.2 Where the stiffening member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

1.19.3 Where the stiffening member is curved then the span is to be taken as the effective chord length between span points.

1.19.4 Where there is a pronounced turn of bilge, chine or the structure is significantly pitched, the span may be measured as in Fig. 3.1.2.

1.19.5 It is assumed that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.

Table 3.1.1 Section modulus, inertia and web area coefficients

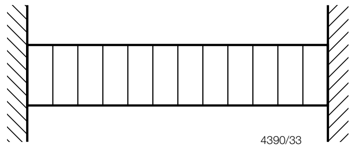
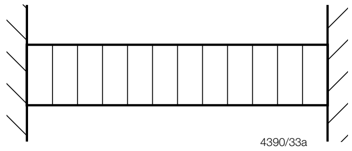
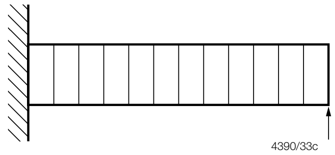
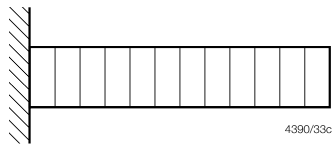
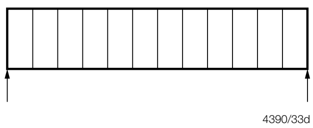
Load model	Position 1 2 3	Position	Web area coefficient Φ_A	Section modulus coefficient Φ_Z	Inertia coefficient Φ_I	Application
(a)		1 2 3	1/2 — 1/2	1/12 1/24 1/12	— 1/384 —	Primary and other members where the end fixity is considered encastre
(b)		1 2 3	1/2 — 1/2	1/10 1/10 1/10	— 1/288 —	Local, secondary and other members where the end fixity is considered to be partial
(c)		1 2 3	5/8 — 3/8	1/8 9/128 —	— 1/185 —	Various
(d)		1 2 3	1 — —	1/2 — —	— — 1/8	Various
(e)		1 2 3	1/2 — 1/2	— 1/8 —	— 5/384 —	Hatch covers, glazing and other members where the ends are simply supported

Table 3.1.2 Stiffener proportions

Type of stiffener	Requirement
(1) Flat bar	Minimum web thickness: $t_w = d_w/18 \quad \geq 2,5$ mm
(2) Rolled or built sections	(a) Minimum web thickness: $t_w = d_w/65 \quad \geq 2,5$ mm (b) Maximum unsupported face plate (or flange) width: $b_f = 16t_f$
Symbols	
t_w = web thickness of stiffener with unstiffened webs, in mm d_w = web depth of stiffener, in mm b_f = face plate (or flange) unsupported width, in mm t_f = face plate (or flange) thickness, in mm	

1.20 Secondary member end connections

1.20.1 Secondary members, that is longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are to be effectively continuous and are to be suitably bracketed at their end connections. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered, *see also* Ch 2,4.16 and Table 2.4.5 in Chapter 2.

1.20.2 Where bracketed end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

1.20.3 The scantlings of secondary member end connections are to be in accordance with 1.21.

1.21 Scantlings of end brackets

1.21.1 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the scantlings of the brackets are to be such that their section modulus and effective cross-sectional area are not less than those of the member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

1.21.2 In other cases the scantlings of the bracket are to be based on the modulus as follows:

(a) Bracket connecting stiffener to primary member – modulus of the stiffener.

(b) Bracket at the head of a main transverse frame where frame terminates – modulus of the frame.

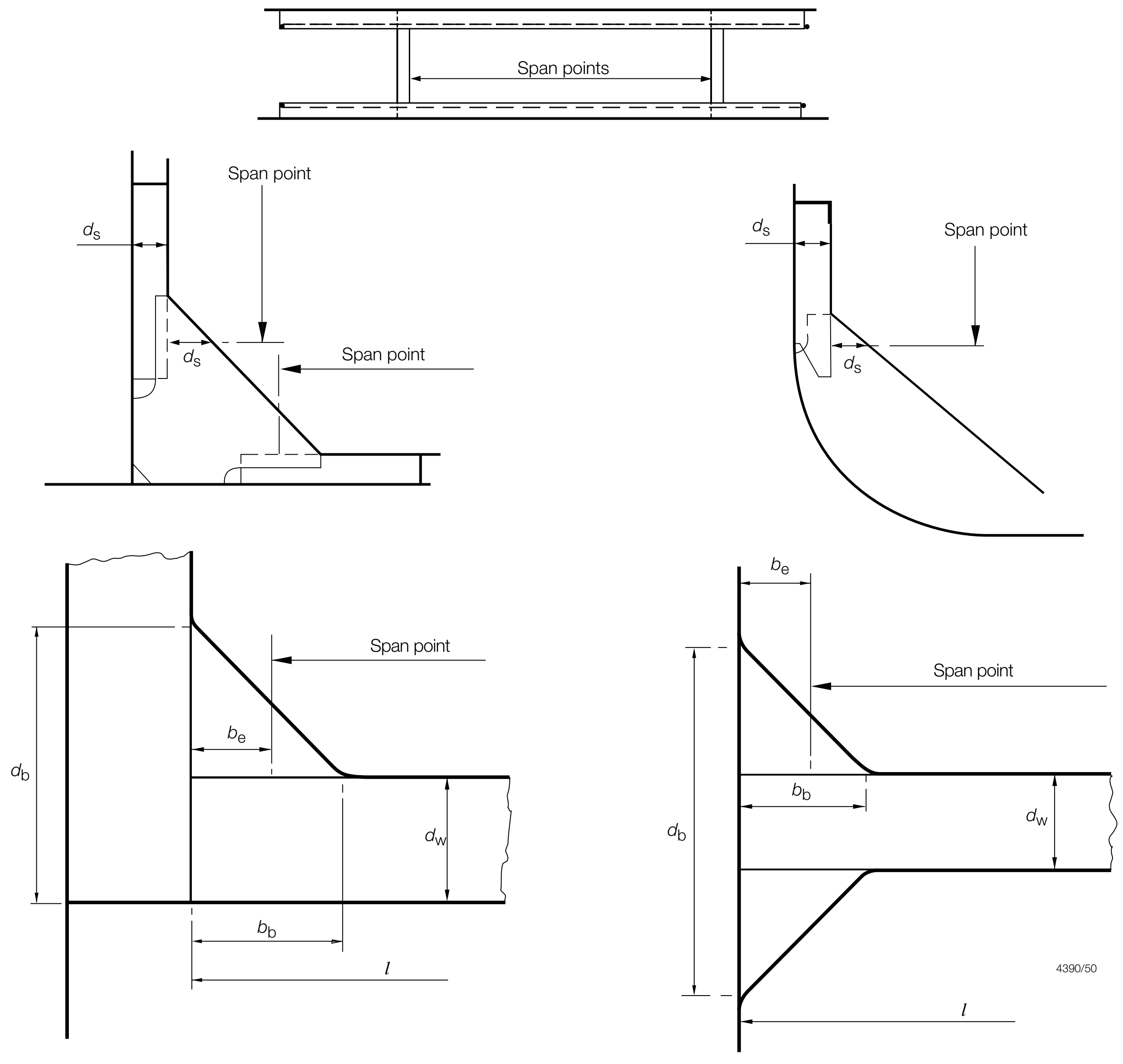


Fig. 3.1.2 Span points

(c) Brackets connecting lower deck beams or longitudinals to the main frame in the forward $0{,}5L_R$ – modulus of the frame.
(d) Elsewhere – the lesser modulus of the members being connected by the bracket.

1.21.3 The web thickness and face flat area of end brackets are not in general to be less than those of the connecting stiffeners. Additionally, the stiffener proportion requirements of 1.18 are to be satisfied.

1.21.4 Typical arrangements of stiffener end brackets are shown diagrammatically in Fig. 3.1.3.

1.21.5 The lengths, *a* and *b*, of the arms are to be measured from the plating to the toe of the bracket and are to be such that:
(a) $a + b \geq 2{,}0 l_b$
(b) $a \geq 0{,}8 l_b$
(c) $b \geq 0{,}8 l_b$
where *a* and *b* are the actual lengths of the two arms of the bracket, in mm, measured from the plating to the toe of the bracket.

$$l_b = 90\left(2\sqrt{\frac{Z}{14 + \sqrt{Z}}} - 1\right) \text{ mm}$$

Z = the section modulus of the secondary member, in cm^3
In no case is l_b to be taken as less than twice the web depth of the stiffener on which the bracket scantlings are to be based.

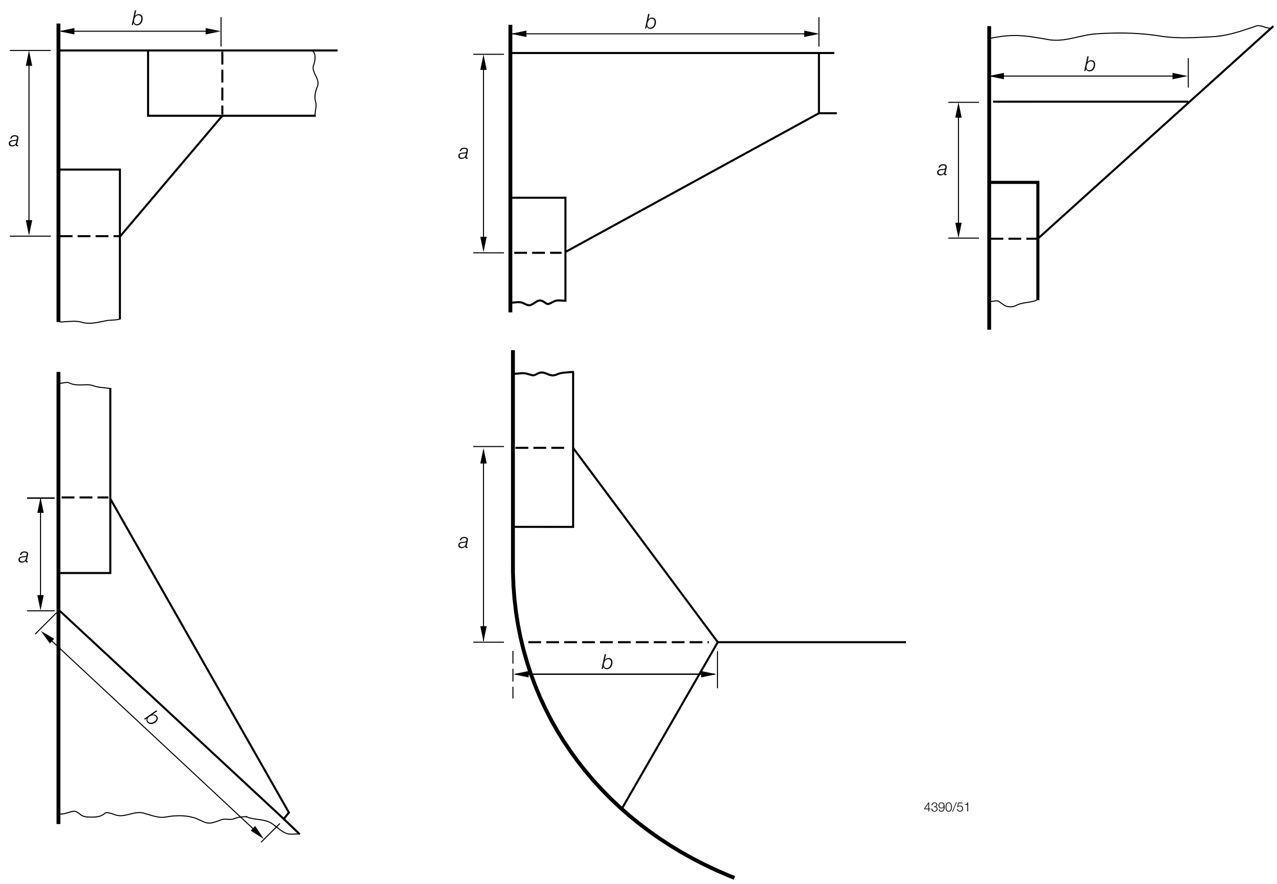


Fig. 3.1.3 Stiffener end brackets

1.21.6 The free edge of the bracket is to be stiffened where any of the following apply:

(a) The section modulus, Z, exceeds 500 cm^3.

(b) The length of free edge exceeds 40 times the bracket thickness.

(c) The bracket is fitted at the lower end of main transverse side framing.

1.21.7 Where a face flat is fitted, its breadth, b_f, is to be not less than:

$$b_f = 40 \left(1 + \frac{Z}{1000}\right) \text{ mm}$$

but not less than 50 mm

1.21.8 Where the edge is stiffened by a welded face flat, the cross-sectional area of the face flat is to be not less than:

(a) $0{,}009 k_s\, b_f\, T_B$ cm^2 for offset edge stiffening.

(b) $0{,}014 k_s\, b_f\, T_B$ cm^2 for symmetrically placed stiffening

where

b_f = breadth of face flat, in mm

T_B = the thickness of the bracket, in mm

k_s is as defined in 1.5.1.

1.21.9 Where the stiffening member is lapped on to the bracket, the length of overlap is to be adequate to provide for the required area of welding. In general, the length of overlap is not to be less than $10\sqrt{Z}$ mm, or the depth of stiffener, whichever is the greater.

1.21.10 Where the free edge of the bracket is hollowed out, it is to be stiffened or increased in size to ensure that the modulus of the bracket through the throat is not less than that of the required straight edged bracket.

1.21.11 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the actual modulus reduced to less than that of the stiffener with associated plating.

1.21.12 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.22 Primary member end connections

1.22.1 The requirements for section modulus and inertia (if applicable) of primary members are given in the appropriate Chapter. The scantling requirements for primary member end connections in dry spaces and in tanks of all craft types are generally to comply with the requirements of 1.21, taking Z as the section modulus of the primary member.

1.22.2 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

1.22.3 The members are to have adequate lateral stability and web stiffening and the structure is to be arranged to minimise hard spots and other sources of stress concentration. Openings are to have well rounded corners and smooth edges and are to be located having regard to the stress distribution and buckling strength of the panel.

1.22.4 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

1.22.5 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended beyond the point of support and thereafter tapered and/or scarfed into the adjacent structure over a distance generally not less than two frame spaces.

1.22.6 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening may be required.

1.22.7 The thickness of the bracket is to be not less than that of the primary member web. The free edge of the bracket is to be stiffened.

1.22.8 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

1.22.9 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Proposals to fit brackets of reduced scantlings, or alternative arrangements, will be considered.

1.22.10 Connections between primary members forming a ring system are to minimise stress concentrations at the junctions. Integral brackets are generally to be radiused or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

1.23 Tank boundary penetrations

1.23.1 Where structural members pass through the boundary of a tank, and leakage into the adjacent space could be hazardous or undesirable, full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively a small scallop of suitable shape may be cut in the member close to the boundary outside the compartment, and carefully welded all round.

1.24 Web stability

1.24.1 Primary members of asymmetrical section are to be supported by tripping brackets at alternate secondary members. If the section is symmetrical, the tripping brackets may be four spaces apart.

1.24.2 Tripping brackets are in general required to be fitted at the toes of end brackets and in way of heavy or concentrated loads such as the heels of pillars. *See also* LR's *Guidance Notes for Structural Details*.

1.25 Openings in the web

1.25.1 Where openings are cut in the web, the depth of opening is not to exceed 50 per cent of the web depth, and the opening is to be so located that the edges are not less than 25 per cent of the web depth from the face plate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered.

1.25.2 Openings are to have smooth edges and well rounded corners.

1.26 Continuity and alignment

1.26.1 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

1.26.2 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment.

1.26.3 Pillars and pillar bulkheads are to be fitted in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

1.26.4 Continuity is to be maintained where primary members intersect and where the members are of the same depth, a suitable gusset plate is to be fitted, *see* Fig. 3.1.4.

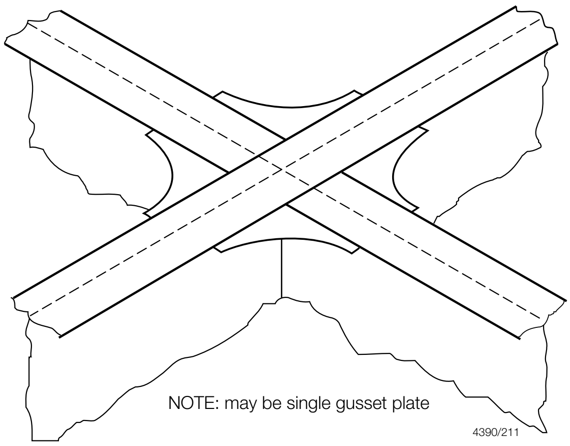


Fig. 3.1.4 Primary member intersection

1.26.5 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

1.26.6 The toes of brackets, etc., are not to land on unstiffened panels of plating. Special care is to be taken to avoid notch effects at the toes of brackets, by making the toe concave or otherwise tapering it off. *See also* LR's *Guidance Notes for Structural Details*.

1.26.7 Particular care is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face plates which are welded onto the edge of primary member brackets are to be carried well around the radiuses bracket toe and are to incorporate a taper not exceeding one in three. Where sniped face plates are welded adjacent to the edge of primary member brackets, adequate cross sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area measured perpendicular to the face plate, is to be not less than 60 per cent of the full cross-sectional area of the face plate, *see* Fig. 3.1.5.

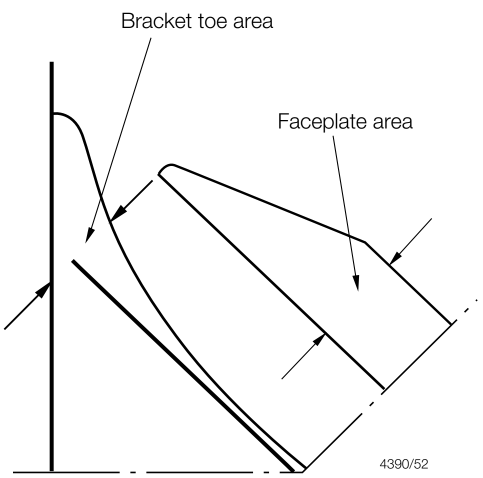


Fig. 3.1.5 Bracket toe construction

1.27 Arrangement with offset stiffener

1.27.1 Where the stiffeners of the double bottom floors and transverse bulkheads are unconnected to the secondary members and offset from them (*see* Fig. 3.1.6) the collar arrangement for the secondary members are to satisfy the requirements of 1.28. In addition, the fillet welds attaching the lugs to the secondary members are to be based on a weld factor of 0,44 for the throat thickness. To facilitate access for welding the offset stiffeners are to be located 50 mm from the slot edge furthest from the web of the secondary member. The ends of the offset stiffeners are to be suitably tapered and softened.

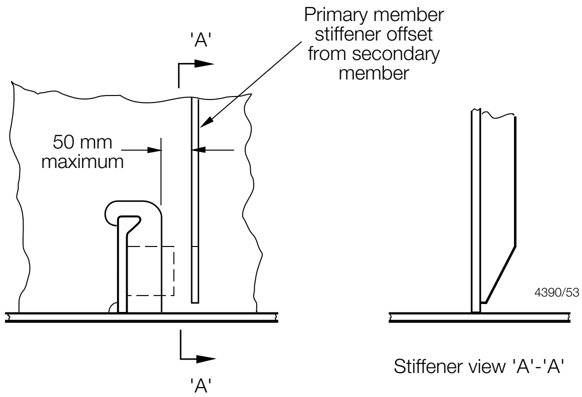


Fig. 3.1.6 Arrangement with offset stiffener

1.27.2 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.28 Arrangements at intersection of continuous secondary and primary members

1.28.1 Cut-outs for the passage of secondary members through the webs of primary members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating. The critical shear buckling stress of the panel in which the cut-out is made is to be investigated. Cut-outs for longitudinals will be required to have double lugs in areas of high stress.

1.28.2 The breadth of cut-outs is to be as small as practicable, with the top edge suitably radiused. Cut-outs are to have smooth edges, and the corner radii are to be as large as practicable, with a minimum of 20 per cent of the breadth of the cut-out or 25 mm, whichever is the greater. It is recommended that the web plate connection to the hull envelope, or bulkhead, end in a smooth tapered 'soft toe'. Recommended shapes of cut-out are shown in Fig. 3.1.7, but consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration. *See also* LR's *Guidance Notes for Structural Details*.

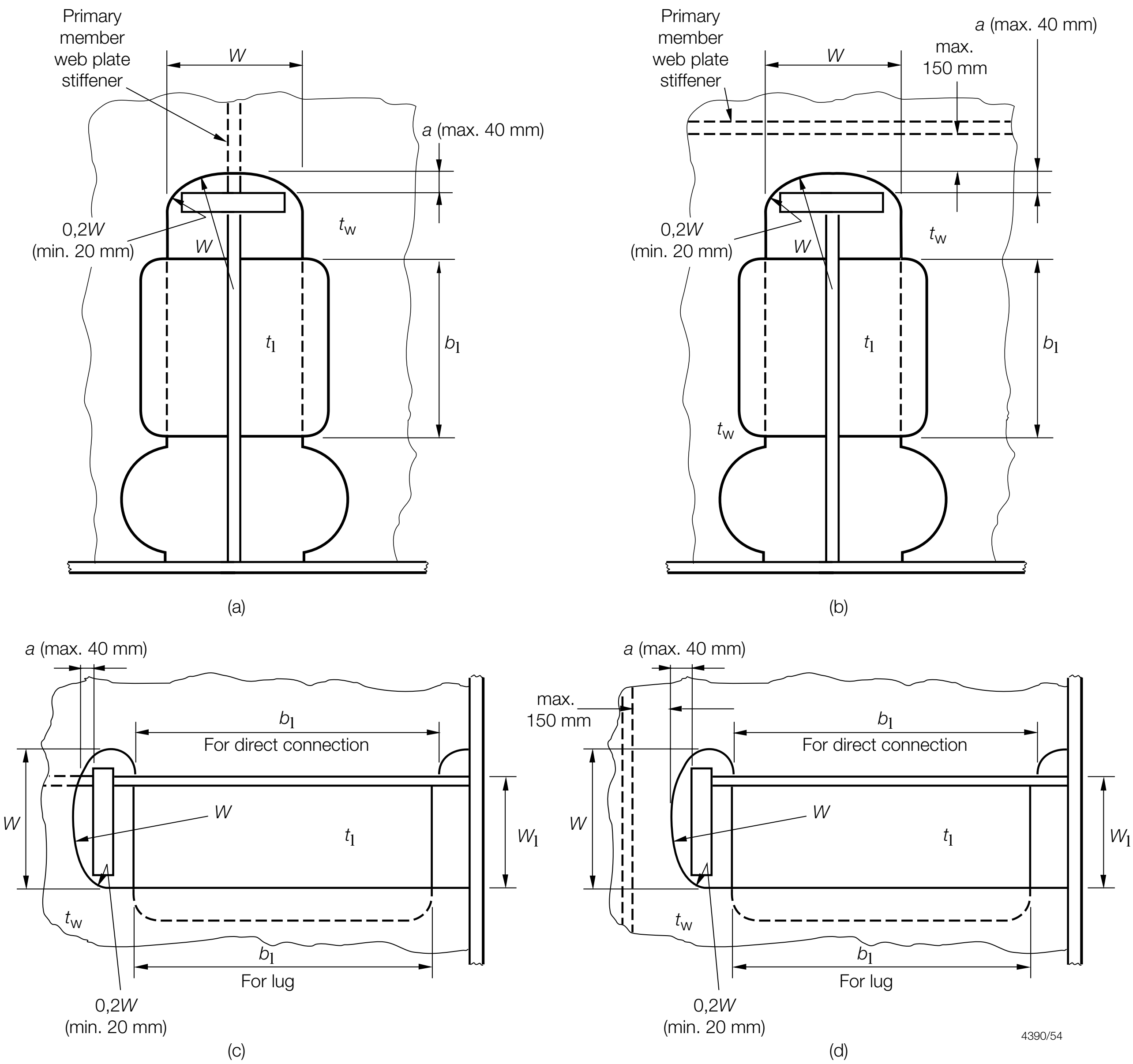


Fig. 3.1.7 Cut-outs and connections

1.28.3 Consideration is to be given to the provision of adequate drainage and unimpeded flow of air and water when designing the cut-outs and connection details.

1.28.4 Asymmetrical secondary members are to be connected on the heel side to the primary member web plate. Additional connection by lugs on the opposite side may be required.

1.28.5 Symmetrical secondary members are to be connected by lugs on one or both sides, as necessary.

1.28.6 Where the primary member stiffener is connected to the secondary member it is to be aligned with the web of the secondary member, except where the face plate of the latter is offset and abutted to the web, in which case the stiffener connection is to be lapped.

1.28.7 Fabricated longitudinals having the face plate welded to the underside of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where it is proposed to fit such sections, a symmetrical arrangement of connection to transverse members is to be incorporated. This can be achieved by fitting backing structure on the opposite side of the transverse web or bulkhead.

1.28.8 Where a bracket is fitted to the primary member web plate in addition to a connected stiffener it is to be arranged on the opposite side to, and in alignment with, the stiffener. The arm length of the bracket is to be not less than the depth of the stiffener, and its cross-sectional area through the throat of the bracket is to be included in the calculation of the area of the primary web stiffener in way of the connection.

1.28.9 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.29 Openings

1.29.1 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or in floors and double bottom girders close to their span ends, or below the heels of pillars, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

1.29.2 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

1.29.3 Air and drain holes, notches and scallops are to be kept at least 200 mm clear of the toes of end brackets and other areas of high stress. Openings are to be well rounded with smooth edges. Closely spaced scallops are not permitted. Widely spaced air or drain holes may be accepted, provided that they are of elliptical shape, or equivalent, to minimise stress concentration and are, in general, cut clear of the weld connection.

1.30 Fittings and attachments, general

1.30.1 The quality of welding and general workmanship of fittings and attachments as given in 1.31 and 1.32 are to be in accordance with Ch 2,3.18.

1.31 Bilge keels and ground bars

1.31.1 It is recommended that bilge keels are not fitted in the forward 0,3L_R region on ships intended to navigate in ice conditions.

1.31.2 Bilge keels are to be attached to a continuous ground bar as shown in Fig. 3.1.8. Butt welds in shell plating, ground bar and bilge keels are to be staggered.

1.31.3 The thickness of the ground bar is to be not less than the thickness of the bottom shell or 6 mm, whichever is the greater, but need not be taken as greater than 12 mm.

1.31.4 The material class, grade and quality of the ground bar are to be similar to those of the adjacent shell plating.

1.31.5 The ground bar is to be connected to the shell with a continuous fillet weld and the bilge keel to the ground bar with a light continuous fillet weld.

1.31.6 Direct connection between ground bar butt welds and shell plating, and between bilge keel butt welds and ground bar is to be avoided.

1.31.7 The end details of bilge keels and intermittent bilge keels, where adopted, are to be as shown in Fig. 3.1.9.

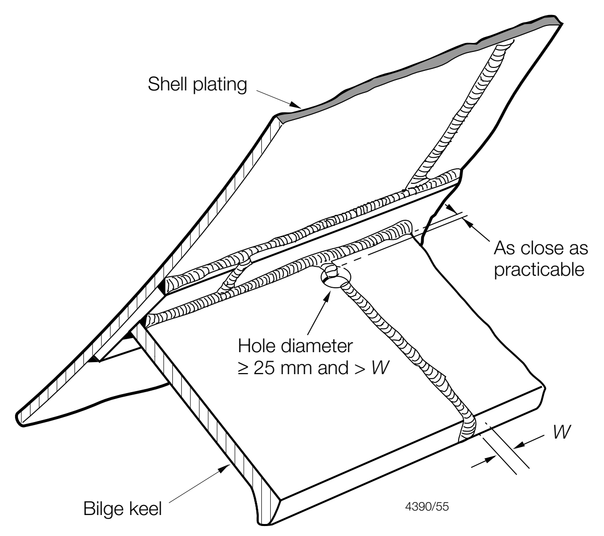


Fig. 3.1.8 Bilge keel construction

1.31.8 The ground bar and bilge keel ends are to be tapered or rounded. Where the ends are tapered, the tapers are to be gradual with ratios of at least 3:1, *see* Figs. 3.1.9(a) and (b). Where the ends are rounded, details are to be as shown in Fig. 3.1.9(c). Cut-outs on the bilge keel web within zone ‘A’ (*see* Fig. 3.1.9(b)) are not permitted.

1.31.9 The end of the bilge keel web is to be between 50 mm and 100 mm from the end of the ground bar, *see* Fig. 3.1.9(a).

1.31.10 An internal transverse support is to be positioned as close as possible to halfway between the end of the bilge keel web and the end of the ground bar, *see* Fig. 3.1.9(b).

1.31.11 Where an internal longitudinal stiffener is fitted in line with the bilge keel web, the longitudinal stiffener is to extend to at least the nearest transverse member outside zone ‘A’, *see* Fig. 3.1.9(b). In this case, the requirement of 1.31.10 does not apply.

1.31.12 For craft over 65 m in length, L_R, holes are to be drilled in the bilge keel butt welds. The size and position of these holes are to be as illustrated in Fig. 3.1.8. Where the butt weld has been subject to non-destructive examination the stop hole may be omitted.

1.31.13 Bilge keels of a different design from that shown in Fig. 3.1.8 and Fig. 3.1.9 will be specially considered.

1.31.14 Within zone ‘B’ (*see* Fig. 3.1.9(a)), welds at the ends of the ground bar and the bilge plating, and at the ends of the bilge keel web and ground bar, are to have weld factors of 0,44 and 0,34 respectively. These welds are to be ground and to blend smoothly with the base materials.

1.31.15 A plan of the bilge keels is to be submitted for approval of material grades, welded connections and detail design.

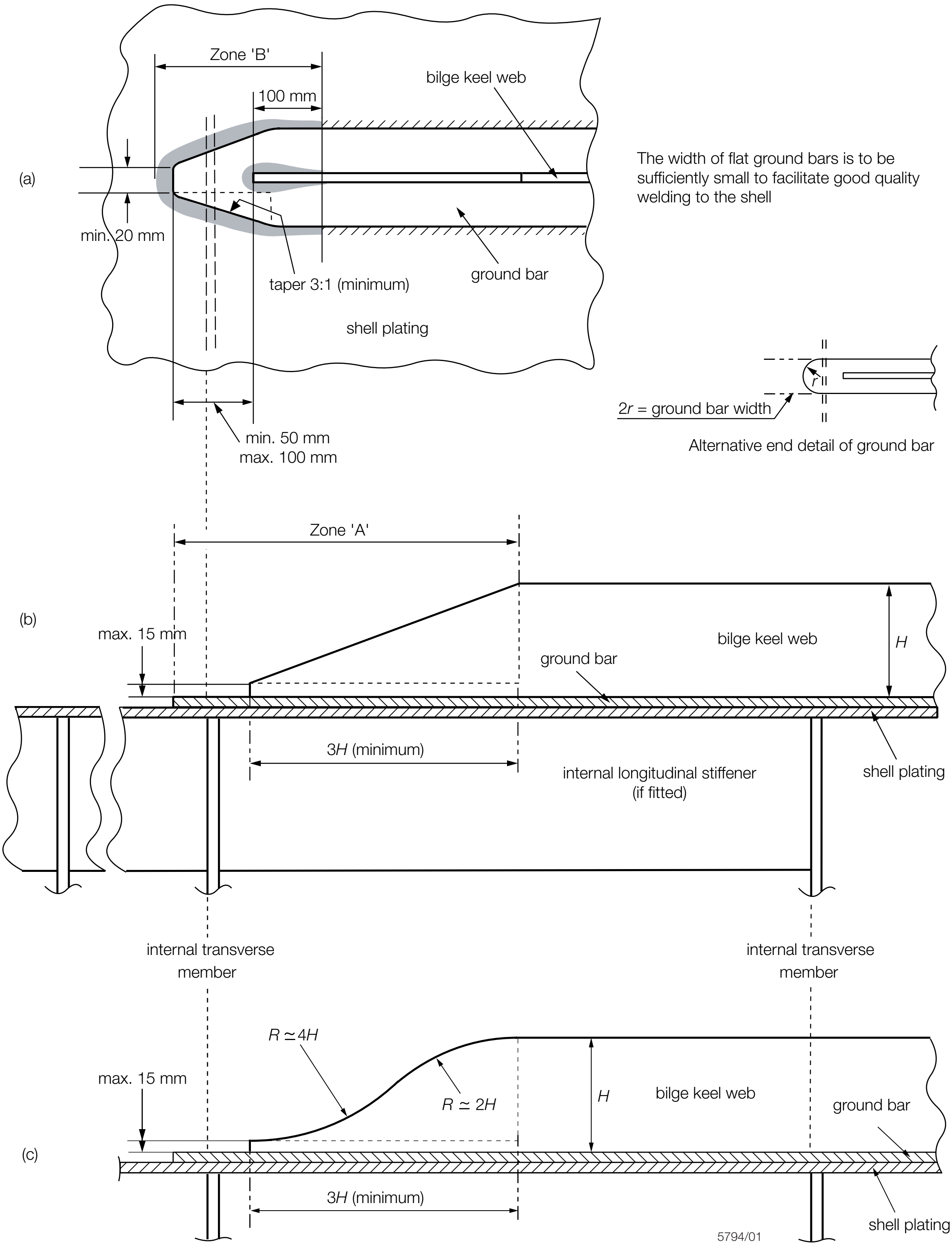


Fig. 3.1.9 Bilge keel end design

1.32 Other fittings and attachments

1.32.1 Gutterway bars at the upper deck are to be so arranged that the effect of main hull stresses on them is minimised.

1.32.2 Minor attachments, such as pipe clips, staging lugs and supports, are generally to be kept clear of toes of end brackets, corners of openings and similar areas of high stress. Where connected to asymmetrical stiffeners, the attachments may be in line with the web provided the fillet weld leg length is clear of the offset face plate or flange edge. Where this cannot be achieved the attachments are to be connected to the web, and in the case of flanged stiffeners they are to be kept at least 25 mm clear of the flange edge. On symmetrical stiffeners, they may be connected to the web or to the centreline of the face plate in line with the web.

1.32.3 Where necessary in the construction of the craft, lifting lugs may be welded to the hull plating but they are not to be slotted through. Where they are subsequently removed, this is to be carried out by mechanical cutting close to the plate surface, and the remaining material and welding ground off. After removal the area is to be carefully examined to ensure freedom from cracks or other defects in the plate surface.

■ *Section 2* Minimum thickness requirements

2.1 General

2.1.1 The thickness of plating and stiffeners determined from the Rule scantling requirements is in no case to be less than that given in Table 3.2.1 for the craft type.

2.1.2 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy the global strength requirements detailed in Chapter 6.

2.2 Corrosion margin

2.2.1 The minimum thicknesses given in Table 3.2.1 are based on the assumption that there is negligible loss in strength by corrosion. Where this is not the case the minimum thickness will be specially considered.

2.3 Impact consideration

2.3.1 Due consideration is to be given to the scantlings of all structure which may be subject to local impact loadings. Impact testing may be required to be carried out at the discretion of LR to demonstrate the suitability of the proposed scantlings for a particular application.

2.4 Sheathing

2.4.1 Areas of shell and deck which are subject to additional wear by abrasion, e.g. from passenger routes, working areas of fishing vessels, forefoot region, etc., are to be suitably protected by local reinforcement or sheathing. This sheathing may be of timber, rubber, steel, additional layers of reinforcement, etc., as appropriate. Details of such sheathing and the method of attachment are to be submitted for consideration.

2.4.2 The attachment of sheathing by mechanical means such as bolting or other methods is not to impair the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable. The design arrangements in way of any through bolting are to be such that damage to the sheathing will not impair the watertight integrity of the hull.

2.5 Operation in ice

2.5.1 The minimum plating thickness of craft intended for operation in ice conditions is to comply with Ch 5,7.

Table 3.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Mono-hull	Hydrofoil	Rigid inflatable boat (RIB)
Shell envelope Bottom shell plating	$\omega\sqrt{k_{ms}}\ (0,4\sqrt{L_R} + 2,0) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,4\sqrt{L_R} + 2,0) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,4\sqrt{L_R} + 2,0) \geq 3,5\omega$
Side shell plating	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R} + 1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R} + 1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R} + 1,2) \geq 3,0\omega$
Single bottom structure Centre girder web	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R} + 1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R} + 1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R} + 1,0) \geq 4,0\omega$
Floor webs	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R} + 0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R} + 0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R} + 0,8) \geq 3,5\omega$
Side girder webs	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R} + 0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R} + 0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R} + 0,8) \geq 3,5\omega$
Double bottom structure Centre girder			
(1) Within $0,4L_R$ amidships	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R} + 1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R} + 1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,8\sqrt{L_R} + 1,0) \geq 4,0\omega$
(2) Outside $0,4L_R$ amidships	$\omega\sqrt{k_{ms}}\ (0,7\sqrt{L_R} + 1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,7\sqrt{L_R} + 1,0) \geq 4,0\omega$	$\omega\sqrt{k_{ms}}\ (0,7\sqrt{L_R} + 1,0) \geq 4,0\omega$
Floors and side girders	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R} + 0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R} + 0,8) \geq 3,5\omega$	$\omega\sqrt{k_{ms}}\ (0,6\sqrt{L_R} + 0,8) \geq 3,5\omega$
Inner bottom plating	$\omega\sqrt{k_{ms}}\ (0,5\sqrt{L_R} + 1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,5\sqrt{L_R} + 1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,5\sqrt{L_R} + 1,0) \geq 2,5\omega$
Bulkheads Watertight bulkhead plating	$\omega\sqrt{k_{ms}}\ (0,33\sqrt{L_R} + 1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,33\sqrt{L_R} + 1,0) \geq 2,5\omega$	$\omega\sqrt{k_{ms}}\ (0,33\sqrt{L_R} + 1,0) \geq 2,5\omega$
Deep tank bulkhead plating	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R} + 1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R} + 1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R} + 1,2) \geq 3,0\omega$
Deck plating and stiffeners Strength/Main deck plating	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R} + 1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R} + 1,2) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,38\sqrt{L_R} + 1,2) \geq 3,0\omega$
Lower deck/Inside deckhouse	$\omega\sqrt{k_{ms}}\ (0,18\sqrt{L_R} + 1,7) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,18\sqrt{L_R} + 1,7) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,18\sqrt{L_R} + 1,7) \geq 2,0\omega$
Superstructures and deckhouses Superstructure side plating	$\omega\sqrt{k_{ms}}\ (0,3\sqrt{L_R} + 1,0) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,3\sqrt{L_R} + 1,0) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,3\sqrt{L_R} + 1,0) \geq 2,0\omega$
Deckhouse front 1st tier	$\omega\sqrt{k_{ms}}\ (0,47\sqrt{L_R} + 1,5) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,47\sqrt{L_R} + 1,5) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,47\sqrt{L_R} + 1,5) \geq 3,0\omega$
Deckhouse front upper tiers	$\omega\sqrt{k_{ms}}\ (0,42\sqrt{L_R} + 1,3) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,42\sqrt{L_R} + 1,3) \geq 3,0\omega$	$\omega\sqrt{k_{ms}}\ (0,42\sqrt{L_R} + 1,3) \geq 3,0\omega$
Deckhouse aft	$\omega\sqrt{k_{ms}}\ (0,2\sqrt{L_R} + 0,6) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,2\sqrt{L_R} + 0,6) \geq 2,0\omega$	$\omega\sqrt{k_{ms}}\ (0,2\sqrt{L_R} + 0,6) \geq 2,0\omega$
Pillars Wall thickness of tubular pillars	$\omega\sqrt{k_{ms}}\ 0,05d_p$	$\omega\sqrt{k_{ms}}\ 0,05d_p$	$\omega\sqrt{k_{ms}}\ 0,05d_p$
Wall thickness of rectangular pillars	$\omega\sqrt{k_{ms}}\ 0,05b_p$	$\omega\sqrt{k_{ms}}\ 0,05d_p$	$\omega\sqrt{k_{ms}}\ 0,05d_p$

Symbols

ω = service type correction factor as determined from Table 3.2.2
k_{ms} = $635/(\sigma_s + \sigma_u)$
σ_s = specified minimum yield strength of the material, in N/mm^2
σ_u = specified minimum ultimate tensile strength of the material, in N/mm^2
b_p = minimum breadth of cross section of hollow rectangle pillar, in mm
d_p = outside diameter of tubular pillar, in mm
L_R is as defined in 1.5.1.

Table 3.2.2 Service type correction factor (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,0
Patrol	1,0
Pilot	1,1
Yacht	1,0
Workboat MFV	1,2

Section 3
Shell envelope plating

3.1 General

3.1.1 The requirements of this Section are applicable to longitudinally and transversely framed shell envelope plating.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in Section 2.

3.2 Plate keel

3.2.1 The breadth, b_k, and thickness, t_k, of the plate keel are not to be taken as less than:

$$b_k = 7{,}0L_R + 340 \text{ mm}$$

$$t_k = \sqrt{k_s}\ 1{,}35L_R^{0{,}45} \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

3.2.2 In no case is the thickness of the plate keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of the plate keel are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by 3.3.1 for the stem.

3.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

3.2.5 For bar keels, *see* 5.2.2.

3.3 Plate stem

3.3.1 The thickness of plate stems, t_S, is not to be taken as less than:

$$t_s = \sqrt{k_s}\ (0{,}1L_R + 3) \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

3.3.2 In no case is the thickness of the plate stem to be taken as less than the thickness of the adjacent shell plating.

3.3.3 Plate stems are to be supported by horizontal diaphragms, and where the stem radius is large, a centreline stiffener or web may be required. Where this is impracticable due to fabrication access considerations, alternative supporting arrangements will be specially considered

3.3.4 For large or novel craft the scantlings of the stem will be specially considered.

3.3.5 The breadth of plate stems is to be not less than the width of keel as required by 3.2.1.

3.4 Bottom shell plating

3.4.1 The thickness of the bottom shell plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types the minimum thickness requirement for bottom shell plating, *see* Fig. 3.3.1, as detailed in Section 2, is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

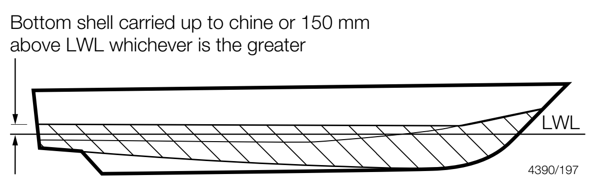


Fig. 3.3.1 Extent of bottom shell

3.5 Side shell plating

3.5.1 The thickness of the side shell plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.6 Sheerstrake

3.6.1 The sheerstrake is generally to be taken as the side shell, locally reinforced in way of deck/hull connection and fender attachment. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service.

3.6.2 The fendering arrangements for all craft types are the responsibility of the designers/Builders and are outside the scope of classification.

3.6.3 Where the pressure or impact loadings that a particular type of craft will experience in service are considered by the Builder, or subsequent Owner, to be not covered by or be greater than those indicated in Part 5 of the Rules, details of the loadings together with the calculations of how these will be satisfactorily distributed into the craft's structure, are to be submitted for consideration with the relevant construction plans.

3.6.4 The arrangements indicated in 3.6.5, 3.6.6, 4.18.2 and 4.18.3 for pilot and fishing craft are for the guidance of the Builder and subsequent Owners/operators of the craft. Where the intended service for either of these types of craft, or other types of craft which may be subject to loadings resulting from contact with other craft, jetties or similar loading or boarding facilities, is such that the loadings are greater than those that can be satisfactorily distributed into the craft's structure by the arrangements indicated, the strengthening arrangements are to be increased accordingly.

3.6.5 For pilot craft which may be subject to repeated impact loadings from contact with other craft etc., the sheerstrake plating is to be increased locally by not less than 50 per cent of the side shell thickness. The increased thickness is to extend from the bow aft over a distance of 0,33L_R or 500 mm aft of the point at which the deckline reaches its greatest breadth, whichever is the greater and forward of the quarter and over the transom for a distance of 0,075L_R or 1,0 m, whichever is the greater. It is in general to extend from the deck edge to below the first longitudinal stiffener, or a vertical distance equivalent to 1/3 the freeboard height whichever is the greater. The additional thickness is then to be tapered out to the side shell thickness in accordance with the Rules.

3.6.6 Fishing craft are in general to have their shell plating scantlings as required to satisfy the Rule loadings, increased by 20 per cent. Additionally the side shell is not to be taken less than as bottom shell thickness, and where there are gallows, gantries, nets, or lines etc., the plating in way is to be further increased locally and/or suitably protected by sheathing or other means.

3.6.7 Individual consideration will be given to lesser scantlings than those required by 3.6.3. for fishing craft used for pleasure, light duties, etc.; details of the service are to be submitted.

3.6.8 Where a rounded sheerstrake is adopted the radius is, in general, to be not less than 15 times the thickness.

3.6.9 The sheerstrake thickness is to be increased by 20 per cent at the ends of a bridge superstructure extending out to the craft's side. In the case of a bridge superstructure exceeding 0,15L_R, the side plating at the ends of the superstructure is also to be increased by 25 per cent and tapered gradually into the upper deck sheerstrake.

3.6.10 In general, compensation will not be required for openings in the sheerstrake which are clear of the gunwale or deck openings and whose depth does not exceed 20 per cent of the depth of the sheerstrake. Openings are not to be cut in a rounded gunwale.

3.7 Chines

3.7.1 The chine plate thickness is to be equivalent to the bottom shell thickness required to satisfy the Rule pressure loading, increased by 20 per cent, or 6 mm, whichever is the greater.

3.7.2 Where tube is used in chine construction, the minimum wall thickness is to be not less than the thickness of the bottom shell plating increased by 20 per cent.

3.7.3 Full penetration welding of shell plating in way of chines is always to be maintained.

3.7.4 Chine details are to be such that the continuity of structural strength across the panel is maintained. Details of chines are to be submitted for consideration. *See also* LR's *Guidance Notes for Structural Details.*

3.8 Skegs

3.8.1 The thickness of the skeg plating is to be not less than the thickness of the adjacent bottom shell and additionally is to satisfy the requirements for solepieces given in Pt 3, Ch 3,3.

3.9 Transom

3.9.1 The thickness of the stern or transom is to be not less than that required for the side or bottom shell as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.10 Fin and tuck

3.10.1 The thickness of the plating is to be increased locally in way of the fin and tuck areas of yachts which have either internal fixed ballast or external attached ballast keels.

3.10.2 The plating thickness is to be not less than 1,25 times the thickness of the adjacent shell plating but need not be greater than the plate keel thickness as required by 3.2.

3.11 Shell openings

3.11.1 Sea-inlets, or other openings, are to have well rounded corners and, so far as is practicable, are to be kept clear of the bilge radius, chine or radiused sheerstrake. Arrangements are to be made to maintain the strength in way of the openings.

3.11.2 Openings on or near the bilge radius may be accepted provided that they are of elliptical shape, or equivalent, to minimize stress concentrations and are, in general, to be cut clear of weld connections.

3.12 Sea inlet boxes

3.12.1 The thickness of the sea inlet box plating is to be 2 mm thicker than the adjacent shell plating, or 6 mm, whichever is the greater.

3.13 Local reinforcement/Insert plates

3.13.1 The thickness of the shell envelope plating determined in accordance with 3.4 and 3.5 is to be increased locally, by generally not less than 50 per cent in way of sternframe, propeller brackets, rudder horn, stabilizers, hawse pipes, anchor recess, etc. Details of such reinforcement are to be submitted for approval.

3.13.2 Insert plates are to extend outside the line of adjacent supporting structure and then be tapered over a distance of not less than three times the difference in thickness, *see also* Ch 2,4.22.

3.14 Appendages

3.14.1 The scantlings of appendages will be subject to special consideration on the basis of the Rules and the design loadings anticipated, but are, in no case, to be taken as less than that of the surrounding structure.

3.15 Fender attachment

3.15.1 Wood belting and fenders are to be bolted to lugs welded to a ground bar attached to the shell and not through-bolted to the shell plating.

3.16 Novel features

3.16.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculation. Such calculations are to be carried out on the basis of the Rules or recognized standards. Details are to be submitted for consideration.

■ *Section 4* Shell envelope framing

4.1 General

4.1.1 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.1.2 For each stiffening member an assumed load model is stated. Where the proposed stiffener arrangement differs from that assumed, consideration will be given to an alternative load model.

4.1.3 The geometric properties of stiffener sections are to be in accordance with 1.18.

4.2 Bottom longitudinal stiffeners

4.2.1 Bottom longitudinal stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is proposed to terminate the bottom longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.3 Bottom longitudinal primary stiffeners

4.3.1 Bottom longitudinal primary stiffeners are to be supported by bottom deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.3.2 Bottom longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be ‘soft toed’ and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.4 Bottom transverse stiffeners

4.4.1 Bottom transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.5 Bottom transverse frames

4.5.1 Bottom transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.6 Bottom transverse web frames

4.6.1 Bottom transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is proposed to terminate the bottom transverse web frames in way of longitudinal primary girders, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.7 Side longitudinal stiffeners

4.7.1 The side longitudinal stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.7.2 Side longitudinals are to be continuous through the supporting structures.

4.7.3 Where it is impracticable to comply with the requirements of 4.7.2, or where it is proposed to terminate the side longitudinal in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.7.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.8 Side longitudinal primary stiffeners

4.8.1 Side longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.8.2 Side longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.8.3 Where it is impracticable to comply with the requirements of 4.8.2, or where it is proposed to terminate the side longitudinal in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.8.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.9 Side transverse stiffeners

4.9.1 Side transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

4.9.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.10 Side transverse frames

4.10.1 Side transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.10.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.11 Side transverse web frames

4.11.1 Side transverse web frames are defined as primary stiffening members which support side shell longitudinals. They are to be continuous and substantially bracketed at their head and heel connections to deck transverses and bottom web frames respectively.

4.11.2 Where it is impracticable to comply with the requirements of 4.11.1, or where it is proposed to terminate the web frames in way of side longitudinal primary stiffeners, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.11.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.12 Grouped frames

4.12.1 For the purposes of satisfying Rule scantling requirements, frames may, subject to agreement by LR, be grouped. The number of frames in any group shall not in general exceed five. The summation of the section moduli and inertia for the group of frames is not to be less than the summation of the Rule requirement for the individual framing members. In addition, in no case is the proposed scantling of an individual framing member within the group to be less than ninety per cent of the Rule value for that member.

4.13 Grillage structures

4.13.1 For complex girder systems, a complete structural analysis using numerical methods may have to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

4.13.2 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

4.13.3 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

4.14 Combined framing systems

4.14.1 Where longitudinal and transverse primary stiffeners form grillage structures the scantlings may be derived in accordance with 4.13.

4.15 Floating framing systems

4.15.1 Floating framing systems, where proposed, will be subject to special consideration.

4.16 Frame struts

4.16.1 Where struts are fitted to side shell transverse web frames or longitudinal primary stiffeners to carry axial loads, the strut cross-sectional area is to be derived as for pillars in Section 10. If fitted at the stiffener half span point, the stiffener section modulus may be taken as half the modulus derived above.

4.16.2 Design of end connections is to be such that the area of the welding is to be not less than the minimum cross-sectional area of the strut derived in 4.16.1. To achieve this, full penetration welding may be required. The weld connections between the face flats and webs of the pillar supporting structure are to be welded using double continuous welding of an equivalent area to that derived by 4.16.1.

4.17 Arrangements and details

4.17.1 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection are the section modulus and inertia reduced to less than that of the stiffener with associated plating.

4.17.2 The web stability, openings in the web and continuity and alignment are to be in accordance with 1.24, 1.25 and 1.26 respectively.

4.17.3 Secondary and primary end connections and arrangements at intersection of continuous secondary and primary members are to be in accordance with 1.20, 1.22 and 1.28, respectively.

4.17.4 Stiffeners in slamming areas are to be lugged or bracketed.

4.18 Structure in way of fenders

4.18.1 **For craft**, including pilot boats and fishing vessels, which may be subject to repeated impact loadings from contact with other craft whilst in service, due consideration is to be given to increasing the scantlings of stiffening members in way of fenders. Details of anticipated loadings and calculations for the required increased scantlings are to be submitted, *see also* 3.6.3 and 3.6.4.

4.18.2 **Pilot craft** are to be fitted with large knees in way of the sheerstrake in areas as indicated in 3.6. The knees are to be aligned between the transverse frames and the deck beams. In the case of longitudinally framed craft, intermediate knees are to be fitted with a spacing in general not greater than 500 mm. Where such intermediate brackets are fitted they are to terminate on a side longitudinal with a section modulus of, in general, twice that of the Rule longitudinal for the web frame spacing, and a deck longitudinal. The side longitudinal is to be positioned below any fendering to carry the heel of the knee. Consideration will be given to the termination of such brackets by use of a 'soft-toe' in way of the deck. The thickness of the webs for these knees is to be twice that required by 1.21.

4.18.3 **Fishing craft** engaged in pair trawling and other modes of fishing, and which may be subject to repeated impact loading from contact with the other craft are to have additional stiffening fitted in way of the impact areas. This may be in the form of large knees, intermediate knees, substantial fendering/rubbing strakes.

4.19 Novel features

4.19.1 The scantlings are to be determined by direct calculation where the shell framing is of unusual design, form or proportions.

■ *Section 5*
Single bottom structure and appendages

5.1 General

5.1.1 The requirements of this Section provide for single bottom construction in association with transverse and longitudinal framing systems.

5.1.2 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

5.1.3 Particular care is to be taken to ensure that the continuity of structural strength in way of the intersection of transverse floors and longitudinal girders is maintained. The face flats of such stiffening members are to be effectively connected.

5.1.4 The single bottom structure in way of the keel and girders is to be sufficient to withstand the forces imposed by dry-docking the craft.

5.1.5 The scantlings of the single bottom structure are to comply with the appropriate minimum requirements given in Section 2.

5.2 Keel

5.2.1 The breadth, and thickness of plate keels are to comply with the requirements of 3.2.

5.2.2 The cross-sectional area, A_k, and thickness, t_k, of bar keels are not, in general, be taken as less than:

$$A_k = k_s (L_R + 1) \text{ cm}^2$$
$$t_k = \sqrt{k_s} \; (0{,}5L_R + 6) \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.3 Centre girder

5.3.1 A centreline girder is, in general, to be fitted throughout the length of the hull in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders are to be formed of intercostal or continuous plate webs with a face flat welded to the upper edge. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement will be required to maintain the continuity of structural strength.

5.3.3 The web depth of the centre girder is in general to be equal to the depth of the floors at the centreline as specified in 5.5.3.

5.3.4 The web thickness, t_w, is to be taken not less than:

$$t_w = \sqrt{k_s} \; (\sqrt{L_R} + 1) \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.3.5 The geometric properties of the centre girder are to be in accordance with 1.18.

5.3.6 The face flat area of the centre girder, A_f, is to be not less than:

$$A_f = 0{,}3 L_R \, k_s \text{ cm}^2$$

where

L_R and k_s are as defined in 1.5.1.

5.3.7 The face flat area of the centre girder outside $0{,}5L_R$ may be 80 per cent of the value given in 5.3.6.

5.3.8 The face flat thickness is to be not less than the thickness of the web.

5.3.9 The ratio of the width to thickness of the face flat is to be not less than 8 but is not to exceed 16.

5.3.10 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 6,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 metres. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The web thickness of side girders is to be taken as not less than:

$$t_w = \sqrt{(k_s \, L_R)} \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.4.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in 5.5.6 and 5.5.7.

5.4.4 Watertight side girders and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deeptanks as detailed in 7.3 and 7.5 respectively.

5.4.5 In the engineroom, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.4.6 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

5.5 Floors general

5.5.1 In transversely framed craft, plate floors are generally to be fitted at each frame.

5.5.2 In longitudinally framed craft, plate floors are to be fitted at every transverse web frame and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are in general to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft forward.

5.5.3 The overall depth, d_f, of plate floors at the centreline is not to be taken as less than:

when $B < 10$ m $\quad d_f = 40\,(B + 0{,}85D)$ mm

when $B \geq 10$ m $\quad d_f = 40\,(1{,}5B + 0{,}85D) - 200$ mm

where

D is defined in Pt 3, Ch 1,6.2.6

B is as defined in 1.5.1.

5.5.4 The web thickness, t_w, of plate floors, is to be accordance with 1.18 and is to be taken as not less than:

$$t_w = \sqrt{k_s}\left(\frac{3{,}4 d_f}{1000} + 2{,}25\right)\left(\frac{s}{1000} + 0{,}5\right) \text{ mm}$$

where

d_f is to be determined from 5.5.3

k_s and s are as defined in 1.5.1.

5.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.6 The face flat area of floors, A_f, is not to be taken as less than:

$$A_f = k_s \, 0{,}15 L_R \text{ cm}^2$$

where

k_s and L_R are defined in 1.5.1.

5.5.7 The face flat thickness is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than 8 but is not to exceed 16.

5.5.8 Additionally the requirements of 4.6 for bottom transverse web frames are to be complied with.

5.5.9 Floors are generally to be continuous from side to side.

5.5.10 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.11 The floors in the aft peak are to extend over and provide effective support to the stern tube(s) where applicable.

5.5.12 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in 7.3 and 7.5.

5.6 Floors in machinery spaces

5.6.1 The thickness, t_W, of the floors in machinery spaces is to be 1 mm greater than that required by 5.5.4.

5.6.2 The depth and section modulus of floors anywhere between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The face flat area and web thickness for such reduced floor heights are to be increased appropriately in order to maintain continuity of structural strength, *see also* 4.12.

5.7 Machinery seatings

5.7.1 The general requirements for machinery seatings are given in Pt 3, Ch 2,6.9, *see also* Pt 9, Ch 1,5.

5.7.2 Engine holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders. When this cannot be achieved, bracket floors are to be fitted.

5.7.3 Welding in way of machinery seatings is to be double continuous and/or full penetration where appropriate.

5.8 Drainholes in bottom structure

5.8.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

5.8.2 Particular care is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

5.8.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

5.9 Rudder horns

5.9.1 The shell plating thickness in way of the rudder horn is to be increased locally, by generally not less than 50 per cent, but need not be taken as greater than the keel thickness required by 3.2.

5.9.2 The scantlings of the rudder horn are to be such that the section modulus against transverse bending, Z_r, at any horizontal section XX (*see* Fig. 3.5.1) is not less than:

$$Z_r = 1{,}5 k_s R_A K_V (V + 3)^2 \sqrt{a^2 + 0{,}5 b^2} \quad \text{cm}^3$$

where

R_A = total rudder area, in m^2
V = maximum speed in the fully loaded condition, in knots
K_V = 1,0 for displacement craft with $V/\sqrt{L_{WL}} < 3{,}0$
= $(1{,}12 - 0{,}005V)^3$ for planing and semi-planing craft with $V/\sqrt{L_{WL}} \geq 3{,}0$
a, b = dimensions, in metres, as given in Fig. 3.5.1
L_{WL} is as defined in Pt 3, Ch 1,6.2.5.

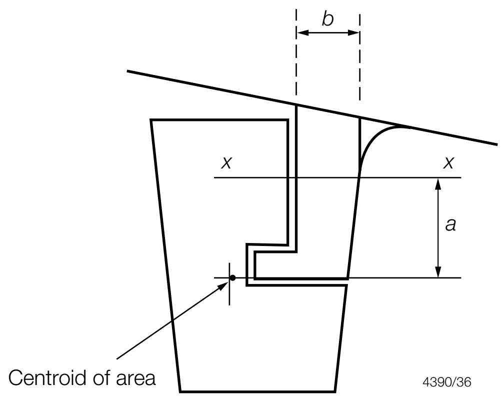


Fig. 3.5.1 Rudder horn

5.9.3 Rudder horns are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

5.10 Sternframes

5.10.1 The scantlings of fabricated and forged/solid sternframes are to comply with the requirements of Pt 3, Ch 3,3 modified for appropriate grade of steel in accordance with Pt 3, Ch 3,1.2.

5.11 Skeg construction

5.11.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

5.11.2 The scantlings and arrangements for skegs (solepieces) are to be in accordance with Pt 3, Ch 3,3.14.

5.11.3 The scantlings of skegs are to be sufficient to withstand any docking forces that they may be subjected to.

5.12 Forefoot and stem

5.12.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 3.2.

5.12.2 The forefoot and stem is to be additionally reinforced with floors.

5.12.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than:

$$A_{bs} = 0{,}8 k_s L_R \quad \text{cm}^2$$

where
L_R and k_s are as defined in 1.5.1.

5.13 Transom knee

5.13.1 Centre and side girders are to be bracketed to the transom framing members by means of substantial knees. The face flat of the girders may be gradually reduced to that of the transom stiffening members in accordance with Fig. 3.5.2.

5.13.2 Hard spots are to be avoided in way of the end connections and care is to be taken to ensure that the stiffening member to which the transom knee is bracketed can satisfactorily carry the transmitted loads.

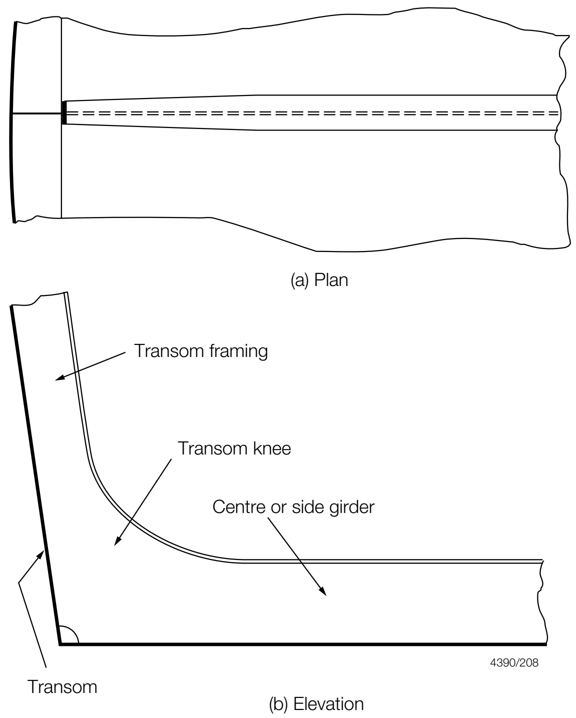


Fig. 3.5.2 Transom knee

■ *Section 6* Double bottom structure

6.1 General

6.1.1 The requirements given in this Section provide for double bottom construction of steel mono-hull craft in association with either transverse or longitudinal framing.

6.1.2 Double bottoms are generally to be fitted in accordance with Pt 3, Ch 2,6.6 and where fitted are to extend from the collision bulkhead to the after peak bulkhead, as far as this is practicable within the design and proper working of the craft. In addition, the inner bottom is to be continued to the craft's side in such a manner as to protect the bottom to the turn of bilge or chine.

6.1.3 The double bottom structure in way of girders and duct keels is to be sufficient to withstand the forces imposed by dry-docking the craft.

6.1.4 The centreline girder and side girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

6.1.5 The scantlings of the double bottom structure are to comply with the appropriate minimum requirements given in Section 2.

6.2 Keel

6.2.1 The scantlings of bar and plate keels are to comply with the requirements of 5.3.

6.2.2 Duct keels, where arranged, are to have a side plate thickness not less than:

$$t_p = \sqrt{k_s}\ (0{,}008 d_{DB} + 1) \quad \text{mm}$$

but need not be taken as greater than 90 per cent of the centre girder thickness given in 6.3.

where

d_{DB} is the Rule centre girder depth given in 6.3.3

k_s as defined in 1.5.1.

6.2.3 Where a duct keel forms the boundary of a tank, the requirements of 7.4 and 7.5 for deep tanks are to be complied with.

6.2.4 The duct keel width is in general to be 15 per cent of the beam or 2 m, whichever is the lesser, but in no case is it to be taken as less than 630 mm. The inner bottom and bottom shell within the duct keel are to be suitably stiffened with primary stiffening in the transverse direction, whilst the continuity of the floors is maintained. Access to the duct keel is to be by means of watertight manholes or trunks.

6.3 Centre girder

6.3.1 A centre girder is to be fitted throughout the length of the craft. The web thickness, t_w, is not to be less than that required by:

$$t_w = \sqrt{k_s}\ (0{,}1L_R + 3) \ \text{mm within } 0{,}4L_R \text{ amidships}$$
$$= \sqrt{k_s}\ (0{,}1L_R + 2) \ \text{mm at ends.}$$

where

k_s and L_R as defined in 1.5.1.

6.3.2 The geometric properties of the girder section are to be in accordance with 1.18.

6.3.3 The overall depth of the centre girder, d_{DB}, is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the floor breadth does not exceed 6,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 6,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 3,0 m.

6.4.3 Side girders where fitted are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness of non-watertight plate floors, t_w, is to be not less than:

$$t_w = \sqrt{k_s}\,(0{,}05L_R + 3{,}5) \text{ mm}$$

where

k_s and L_R as defined in 1.5.1.

6.5.2 Additionally, the requirements of 4.6 for bottom transverse web frames stiffeners are to be complied with.

6.5.3 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.4 In longitudinally framed craft, plate floors or equivalent structure are, in general, to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings, and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engine room.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.5 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_w$ and a thickness of not less than t_w,

where

t_w is the thickness of the plate floor as calculated in 6.5.1.

6.5.6 In transversely framed craft, plate floors are to be fitted at every frame in the engine room, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Bracket floors

6.6.1 Between plate floors, the shell and inner bottom plating is to be supported by bracket floors. The brackets are to have the same thickness as plate floors and are to be stiffened on the unsupported edge.

6.6.2 In longitudinally framed craft, the brackets are to extend from the centre girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket to be taken as not less than 75 per cent of the depth of the centre girder. They are to be fitted at every web frame at the margin plate, and those at the centre girder are to be spaced not more than 1,0 m apart.

6.6.3 In transversely framed craft, the breadth of the brackets, attaching the bottom and inner bottom frames to the centre girder and margin plate, is to be not less than 75 per cent of the depth of the centre girder.

6.7 Watertight floors

6.7.1 The scantlings of watertight floors are to comply with the requirements for plate floors as given in 6.5.

6.7.2 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3 or 7.5 respectively.

6.8 Tankside brackets

6.8.1 The scantlings of tankside brackets are to comply with the requirements for plate floors given in 6.5.

6.9 Inner bottom plating

6.9.1 The thickness of the inner bottom plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

6.9.2 Inner bottom plating forming the boundaries of tank spaces is, in addition, to comply with the requirements for water-tight bulkheads or deeptanks as detailed in 7.2 or 7.4 respectively. Where the plating forms vehicle, passenger or other decks the requirements of Section 8 are to be complied with.

6.10 Inner bottom longitudinals

6.10.1 Inner bottom longitudinals are to be supported by inner bottom transverse web frames, floors, bulkheads or other primary structure, generally spaced not more than 2 m apart.

6.10.2 The inner bottom longitudinals are to be continuous through the supporting structure and are to be satisfactorily stiffened against buckling.

6.10.3 Where it is impracticable to comply with the requirements of 6.10.2, or where it is desired to terminate the inner bottom longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.10.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

6.11 Inner bottom transverse web framing

6.11.1 Inner bottom transverse web frames are defined as primary stiffening members which support inner bottom longitudinals. They are to be continuous and to be substantially bracketed at their end connections to bottom web frames, bottom floors and tankside brackets.

6.11.2 Where it is impracticable to comply with the requirements of 6.11.1, or where it is desired to terminate the inner bottom transverse web frames in way of centre or side girders, bulkheads or integral tank boundaries, etc., they are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.11.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

6.12 Margin plates

6.12.1 A margin plate, if fitted, is to have a thickness as required for inner bottom plating.

6.13 Wells

6.13.1 Small wells constructed in the double bottom structure are not to extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted at the after end of the shaft tunnel of the craft. Other well arrangements (e.g. for lubricating oil under main engines) may be considered provided they give protection equivalent to that afforded by the double bottom.

6.14 Transmission of pillar loads

6.14.1 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided, and where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

6.15 Manholes

6.15.1 Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to, and ventilation of, all parts of the double bottom. The size of the manhole openings is not, in general, to exceed 50 per cent of the double bottom depth unless edge reinforcement is provided. Holes are not to be cut in the centre girder, except in tanks at the forward and after ends of the craft, and elsewhere where tank widths are reduced unless additional stiffening and/or compensation is fitted to maintain the structural integrity.

6.16 Pressure testing

6.16.1 Double bottoms are to be tested upon completion with a head of water representing the maximum internal pressure which could be experienced in service, but not less than a head of water equivalent to the level of the upper deck.

6.17 Drainholes in bottom structure

6.17.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

6.17.2 Particular care is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

6.17.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

Section 7
Bulkheads and deep tanks

7.1 General

7.1.1 The requirements of this Section apply to a vertical system of stiffening on bulkheads. They may also be applied to a horizontal system of stiffening provided that equivalent support and alignment are provided.

7.1.2 The number and disposition of transverse watertight bulkheads are to be in accordance with Pt 3, Ch 2,4.

7.1.3 Bulkheads, or part bulkheads, forming the boundary of tanks are to comply with the requirements of 7.5 and 7.6.

7.1.4 For bulkheads in way of partially filled holds or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

7.1.5 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to comply with the requirements of 7.5 and 7.6 for tank boundary bulkheads. If perforated, they are to comply with the requirements of 7.13 for washplates.

7.1.6 The minimum requirements in Section 2 are to be complied with.

7.2 Watertight bulkhead plating

7.2.1 The thickness of the watertight bulkhead plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

7.3 Watertight bulkhead stiffening

7.3.1 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 using the appropriate load model.

7.3.2 Bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.4 Deep tank plating

7.4.1 The thickness of deep tank plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

7.5 Deep tank stiffening

7.5.1 Deep tank bulkhead stiffeners are to be bracketed at both ends. The thickness of the brackets is to be not less than the web thickness of the stiffener.

7.5.2 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4, 3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for load model (b).

7.6 Double bottom tanks

7.6.1 The scantlings of double bottom tanks are to comply with the requirements for deep tanks given in 7.4 and 7.5.

7.6.2 Where the crown of a double bottom tank forms a vehicle, passenger or other deck, the requirements of Section 8 are to be complied with.

7.7 Collision bulkheads

7.7.1 The scantlings of collision bulkheads are to comply with the requirements of 7.2 and 7.3 except that the thickness of plating and modulus of stiffeners are not to be less than 12 and 25 per cent greater respectively, than required by 7.2 and 7.3. If the collision bulkhead forms the boundary of a deep tank or cofferdam then the requirements of 7.4 and 7.5 are also to be complied with.

7.8 Gastight bulkheads

7.8.1 Where gastight bulkheads are fitted, in accordance with Pt 3, Ch 2,4 the scantling requirements for watertight bulkheads are to be complied with.

7.8.2 Gastight bulkheads are to be fitted to protect accommodation spaces from gases and vapour fumes from machinery exhaust and fuel systems.

7.9 Non-watertight or partial bulkheads

7.9.1 Where a bulkhead is structural but non-watertight the scantlings are in general to be as for watertight bulkheads or equivalent in strength to web frames in the same position. Partial bulkheads that are non-structural are outside the scope of LR classification.

7.10 Transmission of pillar loads

7.10.1 Bulkheads that are required to act as pillars in way of underdeck girders and other structures subject to heavy loads are to comply with the requirements of Section 10.

7.11 Corrugated bulkheads

7.11.1 The plating thickness and section modulus for symmetrical corrugated bulkheads are to be in accordance with watertight bulkheads or deep tank bulkheads as appropriate. The spacing, s, is to be taken as s_c, as defined in Fig. 2.3.1 in Pt 3, Ch 2.

7.11.2 In addition, the section geometric properties of 1.18 are to be complied with.

7.11.3 The actual section modulus may be derived in accordance with Pt 3, Ch 2,3.2.

7.12 Stiffeners passing through bulkheads

7.12.1 Primary longitudinal stiffening members are to be continuous through transverse bulkheads.

7.12.2 Pipe or cable runs through watertight bulkheads are to be fitted with suitable watertight glands.

7.13 Wash plates

7.13.1 Tanks are to be sub-divided as necessary by internal baffles or wash plates. Baffles or wash plates which support hull framing are to have scantlings equivalent to web frames in the same position.

7.13.2 Wash plates and wash bulkheads are, in general, to have an area of perforation not less than 10 per cent of the total area of the bulkhead. The perforations are to be so arranged that the efficiency of the bulkhead as a support is not impaired.

7.13.3 The plate thickness is to be not less than the structural element from which the wash bulkhead is formed.

7.13.4 The general stiffener requirements are to be in accordance with 7.5. However, the section modulus may be 50 per cent of that required by 7.5.

7.14 Cofferdams

7.14.1 A cofferdam is to be fitted between freshwater and oil fuel or sanitary tanks. The scantlings of cofferdams are to comply with the requirements of deep tank bulkheads or non-watertight bulkheads as appropriate.

7.15 Coatings

7.15.1 Integral freshwater and oil fuel tanks are to be cleaned and dried after testing and then treated with a suitable coating, in accordance with the manufacturer's recommendations.

7.16 Air pipes

7.16.1 Air pipes of sufficient number and area are to be fitted to each tank in accordance with Pt 15, Ch 2,11.

7.17 Fire protection

7.17.1 Fire protection requirements given in Part 17 are to be complied with.

7.18 Access

7.18.1 Compartments within the craft are to be sufficiently accessible to allow for maintenance and future structural surveys. Linings on craft sides, deckheads and bulkheads, etc., must be capable of being removed. Sufficient space is to be available below lower decks/soles to allow access to the bottom structure. An adequate number of manholes, removable panels, etc., are to provided.

7.18.2 Doors and hatches fitted through watertight bulkheads are to be of equivalent construction to the bulkhead in which they are fitted, be permanently attached and capable of being closed watertight from both sides of the bulkhead. They are to be tested watertight.

7.18.3 Doors and hatches are not to be fitted in collision bulkheads, except in craft of less than 21 metres Rule length, L_R, or in the case where it would be impracticable to arrange access to the forepeak other than through the collision bulkhead. Where fitted, the doors and hatches are to be watertight, as small as practicable and open into the forepeak compartment. Doors in collision bulkheads are to be kept closed at all times while the craft is at sea, *see* Pt 3, Ch 2,4.3.4.

7.18.4 Particular care is to be given to the design and workmanship of the tanks, and adequate access manholes are to be fitted, *see* Pt 3, Ch 1,7.

7.19 Testing

7.19.1 Deep tanks are to be tested on completion, with a head of water to the top of the overflow, or 1,8 m above the crown of the tank, whichever is the greater. The pressure to which the tanks will be subjected to in service is to be indicated on the plans submitted.

■ *Section 8*
Deck structures

8.1 General

8.1.1 The deck plating is to be supported by transverse beams with fore and aft girders or by longitudinals with deep transverse beams. The transverse and deep transverse beams are to align with side main frames and side web frames respectively.

8.1.2 Beams are to be fitted at every frame and bracketed to the frames. Strong beams and deep transverse beams are to align with and be effectively connected to the side web frames. They are also to be fitted at the ends of large openings in the deck.

8.1.3 The deck plating and supporting structure are to be suitably reinforced in way of cranes, masts, derrick posts and deck machinery.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Primary and secondary stiffener end connection arrangements are, in general, to be in accordance with 1.22 and 1.20, respectively.

8.1.7 The ends of beams, longitudinals, girders and transverses are to be effectively built into the adjacent structure, or equivalent arrangements provided.

8.1.8 Tripping brackets are to be fitted on deep webs.

8.1.9 Deck structures subject to concentrated loads, are to be suitably reinforced. Where concentrations of loading on one side of a stiffening member may occur, such as pillars out of line, the member is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

8.1.10 The thickness of the deck plating is in no case to be less than the appropriate minimum requirement given in Section 2.

8.1.11 The geometric properties of stiffener sections are to be in accordance with 1.18.

8.2 Strength/Weather deck plating

8.2.1 The thickness of strength/weather deck plating is to be determined from the general plating equation given in 1.16 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.2.2 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck, *see also* Part 4.

8.2.3 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.2.4 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* 2.4.

8.3 Lower deck/Inside deckhouse plating

8.3.1 The thickness of the lower deck/inside deckhouse plating is to be determined from the general plating equation given in 1.16 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.4 Accommodation deck plating

8.4.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their plating requirements determined in accordance with 8.3.

8.5 Cargo deck plating

8.5.1 The thickness of cargo deck plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.5.2 For vehicle decks, plating thickness requirements are to comply with the requirements of Ch 5,3.

8.6 Decks forming crowns of tanks

8.6.1 Decks forming the crown of tanks are to comply with the requirements for the appropriate deck, and are to be additionally examined for compliance with the requirements for deep tank plating given in 7.4.

8.7 Strength/Weather deck stiffening

8.7.1 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck primary stiffening** are to be determined from the general equations given in 1.17, using the design pressure heads from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

8.7.2 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.7.3 Longitudinal framing is, in general, to be adopted at the strength deck outside line of openings, but special consideration will be given to proposals for transverse framing.

8.8 Lower deck/Inside deckhouse stiffening

8.8.1 The Rule requirements for section modulus, inertia and web area for lower deck/inside deckhouse stiffening are to be determined from the general equations given in 1.17 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.9 Accommodation deck stiffening

8.9.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with 8.8.

8.10 Cargo deck stiffening

8.10.1 The Rule requirements for section modulus, inertia and web area for cargo deck stiffening are to be determined from the general equations given in 1.17 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.10.2 In addition, where the cargo comprises wheeled vehicles, the requirements of Ch 5,3 are to be complied with.

8.11 Deck openings

8.11.1 All openings are to be supported by an adequate framing system, pillars or cantilevers. When cantilevers are used scantlings may be derived from direct calculations.

8.11.2 Where stiffening members terminate in way of an opening they are to be attached to carlings, girders, transverses or coaming plates.

8.11.3 The corners of large hatchways in the strength/weather deck within 0,5L_R amidships are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.4 Where elliptical corners are arranged, the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than two to one nor greater than 2.5 to 1, and the minimum half-length of the major axis is to be defined by l_1 in Fig. 3.8.1. Where parabolic corners are arranged, the dimensions are also to be as shown in Fig. 3.8.1.

8.11.5 Where the corners are parabolic or elliptical, insert plates are not required.

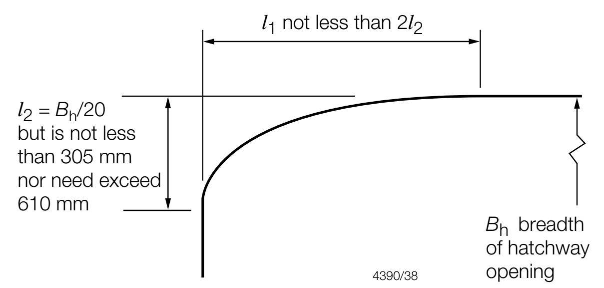


Fig. 3.8.1 Hatch opening geometry

8.11.6 For other shapes of corner, insert plates of the size and extent shown in Fig. 3.8.2 will, in general, be required. The required thickness of the insert plate is to be not less than 25 per cent greater than the adjacent deck thickness, outside line of openings.

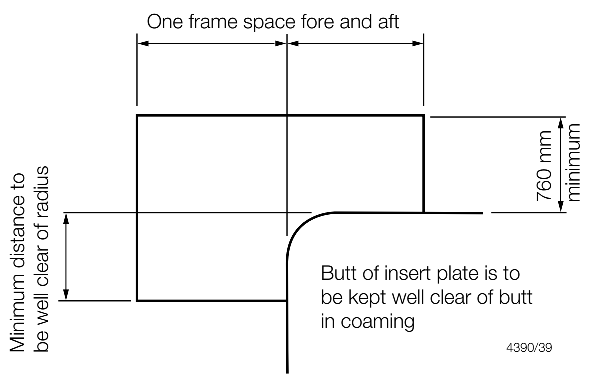


Fig. 3.8.2 Inserts in way of hatch opening

8.11.7 For lower decks the corners of large openings are to be rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.8 Insert plates will be required at lower decks in way of any rapid change in hull form to compensate for loss of deck cross-sectional area. Otherwise, insert plates will not normally be required.

8.11.9 Adequate transverse strength is to be provided in the deck area between large hatch openings, subjected to transverse and buckling loads.

8.11.10 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

8.12 Sheathing

8.12.1 The requirements for deck sheathing given in 2.4 are to be complied with.

8.13 Novel features

8.13.1 Where large or novel hatch openings are proposed, detailed calculations are to be submitted to demonstrate that the scantlings and arrangements in way of the openings are adequate to maintain continuity of structural strength.

■ *Section 9*
Superstructures, deckhouses and bulwarks

9.1 General

9.1.1 Where practicable, superstructures and deckhouses are to be designed with well cambered decks and well radiused corners to build rigidity into the structure.

9.1.2 The plating and supporting structure are to be suitably reinforced in way of localised areas of high stress such as corners of openings, cranes, masts, derrick posts, machinery, fittings and other heavy or vibrating loads.

9.1.3 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

9.1.4 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

9.1.5 Structures subject to concentrated loads are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, such as pillars out of line, the stiffener is to be adequately stiffened against torsion.

9.1.6 The plating thickness of superstructures, deck-houses and bulwarks is no case to be less than the appropriate minimum requirement given in Section 2.

9.1.7 Stiffener sections and geometric properties are to be in accordance with 1.18.

9.2 Symbols and definitions

9.2.1 The term ‘house’ is used in this Section to include both superstructures and deckhouses.

9.2.2 The symbols applicable to this Section are defined in 1.5.1.

9.3 House side plating

9.3.1 The thickness of house side plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.4 House front plating

9.4.1 The thickness of the house front plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.5 House end plating

9.5.1 The thickness of the house end plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.6 House top plating

9.6.1 The thickness of the house top plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.7 Coachroof plating

9.7.1 The thickness of the coachroof plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.8 Machinery casing plating

9.8.1 The thickness of the plating of machinery casings is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.9 Forecastle requirements

9.9.1 The forecastle side plating may be a continuation of the hull side shell plating or fitted as a separate assembly. In both cases the plating thickness is to be the same as the side shell plating at deck edge. Where fitted as a separate assembly, suitable arrangements are to be made to ensure continuity of the effect of the sheerstrake at the break and at the upper edge of the forecastle side. Full penetration welding is to be used.

9.9.2 The side plating is to be stiffened by side frames effectively connected to the deck structure. Deep webs are to be fitted to ensure overall rigidity.

9.9.3 The deck plating thickness is to be increased by 20 per cent in way of the end of the forecastle if this occurs at a position aft of 0,25L_R from the FP. No increase is required if the forecastle end bulkhead lies forward of 0,2L_R from the FP. The increase at intermediate positions of end bulkhead is to be obtained by interpolation.

9.10 House side stiffeners

9.10.1 The Rule requirements for section modulus, inertia and web area for the **house side primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.10.2 The Rule requirements for section modulus, inertia and web area for **house side secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.11 House front stiffeners

9.11.1 The Rule requirements for section modulus, inertia and web area for **house front primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.11.2 The Rule requirements for section modulus, inertia and web area for **house front secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.12 House aft end stiffeners

9.12.1 The Rule requirements for section modulus, inertia and web area for **house aft end primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.12.2 The Rule requirements for section modulus, inertia and web area for **house aft end secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.13 House top stiffeners

9.13.1 The house top is to be effectively supported by a system of transverse or longitudinal beams and girders. The span of the beams is in general not to exceed 2,4 m and the beams are to be effectively connected to the house upper coamings and girders.

9.13.2 The Rule requirements for section modulus, inertia and web area for **house top primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.13.3 The Rule requirements for section modulus, inertia and web area for **house top secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.14 Coachroof stiffeners

9.14.1 The Rule requirements for section modulus, inertia and web area for **coachroof primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.14.2 The Rule requirements for section modulus, inertia and web area for **coachroof secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15 Machinery casing stiffeners

9.15.1 The Rule requirements for section modulus, inertia and web area for **machinery casing primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.15.2 The Rule requirements for section modulus, inertia and web area for **machinery casing secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15.3 Where casing sides act as girders supporting decks, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular care is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

9.15.4 Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably reinforced.

9.16 Forecastle stiffeners

9.16.1 The scantlings of forecastle primary and secondary stiffening members are to be equivalent to those for the side shell envelope framing at the deck edge as required by Section 4.

9.17 Superstructures formed by extending side structures

9.17.1 Superstructure first tier sides formed by extending the hull side structure are to be in accordance with the requirements for house fronts given in 9.4 and 9.11 for plating and stiffeners respectively, but need not be taken as greater than the side structure requirements at the deck edge at the same longitudinal position.

9.18 Fire aspects

9.18.1 The requirements for fire detection, protection and extinction are given in Part 17.

9.19 Openings

9.19.1 All openings are to be substantially framed and have well rounded corners. Arrangements are to be made to minimise the effect of discontinuities in erections. Continuous coamings or girders are to be fitted below and above doors and similar openings.

9.19.2 Particular care is to be paid to the effectiveness of end bulkheads, and the upper deck stiffening in way, when large openings for doors and windows are fitted.

9.19.3 Special care is to be taken to minimise the size and number of openings in the side bulkheads in the region of the ends of erections within $0{,}5L_R$ amidships. Account is to be taken of the high vertical shear loading which can occur in these areas.

9.19.4 For closing arrangements and outfit the requirements are given in Pt 3, Ch 4.

9.20 Mullions

9.20.1 Window openings are to be suitably framed and mullions will in general be required.

9.20.2 The scantlings of mullions are to be not less than as required for a stiffener in the same position.

9.20.3 When determining the stiffener requirements, the width of effective plating is in no case to be taken as greater than the distance between adjacent window openings.

9.20.4 Where significant shear forces are to be vertically transmitted by the window frames, adequate shear rigidity is to be verified by direct calculation.

9.21 Global strength

9.21.1 Transverse rigidity is to be maintained throughout the length of the erection by means of web frames, bulkheads or partial bulkheads. Particular care is to be paid when an upper tier is wider than its supporting tier and when significant loads are carried on the house top.

9.21.2 Where practicable, web frames are to be arranged in line with bulkheads below.

9.21.3 Internal bulkheads are to be fitted in line with bulkheads or deep primary stiffeners below.

9.22 House/deck connection

9.22.1 Adequate support under the ends of erections is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams.

9.22.2 Special attention is to be given to the connection of the erection to the deck in order to provide an adequate load distribution and avoid stress concentrations.

9.22.3 Connections between the erection and the deck by means of bimetallic joints are to comply with Ch 2,4.29.

9.22.4 Typical design details of house/deck connections are given in LR's *Guidance Notes for Structural Details*.

9.23 Sheathing

9.23.1 Sheathing arrangements are to comply with the requirements of 2.4.

9.24 Erections contributing to longitudinal strength

9.24.1 For craft above 40 m in length, L_R, or for designs where the superstructure is designed to absorb global loads the effectiveness of superstructures to carry these loads is to be determined. The effectiveness may be assessed in accordance with Ch 6,2.5.

9.24.2 Where 9.17 applies and the first or second tier is regarded as the strength deck according to Ch 6,2.5, the hull upper deck scantlings at the forward and aft ends of the superstructure may need to be increased due to the lesser efficiency of the superstructure tiers at their ends. The scantlings of the side structure in way of these areas may also be required to be increased.

9.24.3 When large openings or a large number of smaller openings are cut in the superstructure sides, reducing the capability to transmit shear force between decks, an assessment or structural efficiency may be required.

9.25 Novel features

9.25.1 Direct calculations may be required to determine the plating and stiffener requirements where the house is of unusual design, form or proportions.

9.26 Bulwarks

9.26.1 General requirements for bulwarks are given in Pt 3, Ch 4,8.

9.26.2 The thickness of the bulwark plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (d).

9.26.4 Bulwarks are not to be cut for gangway or other openings near the breaks of superstructures.

9.26.5 Attention is to be paid to avoid discontinuity of strength of the bulwark, particularly in way of local increases in stress and changes in height.

9.26.6 Welding of bulwark to the top edge of sheer-strake within $0{,}5L_R$ amidship, is generally to be avoided. However, if this arrangement is not practicable welding to the sheerstrake may be accepted if care is taken to minimise any notch effects.

9.26.7 **Fishing craft** are to have bulwarks fitted. The bulwark may be formed from a continuation of the side shell plating or connected as a separate assembly. Where the bulwark is considered to be stressed and contributing to the global strength of the craft, the plate thickness of the bulwark is not to be less than the sheer-strake thickness. In no case is the thickness of the bulwark plating to be taken as less than 80 per cent of the side shell thickness. The bulwark is to be supported by suitable stiffening members which may be formed from a continuation of the side frames, or from flanged plate stays of the same thickness as the bulwark. In general these frames are to be spaced not more than two side frame spacings apart.

9.26.8 In way of gantries, trawl gallows, mooring pipes etc., the plate thickness in way is to be increased by not less than 50 per cent.

9.26.9 **Pilot craft** are to be fitted with sufficient hand rails adjacent to the exposed areas of the working decks and platforms. In addition these areas are to have non-skid surfaces.

9.27 Freeing arrangements

9.27.1 Requirements for freeing arrangements are given in Pt 3, Ch 4,9.

9.28 Free flow area

9.28.1 The requirements for the free flow area are given in Pt 3, Ch 4,9.3.

9.29 Guard rails

9.29.1 The requirements for guard rails are given in Pt 3, Ch 4,8.4.

■ *Section 10* Pillars and pillar bulkheads

10.1 Application

10.1.1 Pillars are to be arranged to transmit loads from decks and superstructures into the bottom structure. Pillars are generally to be constructed from solid, tubular, or I beam section. A pillar may be a fabricated trunk or partial bulkhead.

10.2 Determination of span length

10.2.1 The effective span length of the pillar, l_{ep}, is in general the distance between the head and heel of the pillar. Where substantial brackets are fitted, l_{ep} may be reduced by 2/3 the depth of the bracket at each end.

10.3 Head and heel connections

10.3.1 Pillars are to be attached at their heads to plates supported by efficient brackets, in order to transmit the load effectively. Doubling or insert plates are to be fitted to decks under large pillars and to the inner bottom under the heels of tubular or hollow square pillars. The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be well distributed by means of longitudinal and transverse brackets.

10.4 Alignment and arrangement

10.4.1 Pillars are to be located on main structural members. They are in general to be fitted below windlasses, winches, capstans, the corners of deckhouses and elsewhere where considered necessary.

10.4.2 Wherever possible, deck pillars are to be fitted in the same vertical line as pillars above and below, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

10.4.3 Where pillars support eccentric loads, or are subjected to lateral pressures, they are to be suitably strengthened for the additional bending moment imposed upon them.

10.4.4 Doublers are generally to be fitted on decks and inner bottoms, other than within tanks where doublers are not allowed. Brackets may be used instead of doublers.

10.5 Minimum thickness

10.5.1 The minimum wall thickness of hollow pillars is to be taken as not less than 1/20 of the external dimension of the pillar.

10.6 Design loads

10.6.1 The design loading, P_p, to be used in the determination of pillar scantlings is as follows:

$$P_p = S_{gt}\, b_{gt}\, P_c + P_a \text{ kN}$$

where

P_p = design load supported by the pillar, to be taken as not less than 5 kN

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over

S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillar, in metres.

10.7 Scantlings determination

10.7.1 The cross-sectional area of the pillar, A_p, is not to be less than:

$$A_p = 10\,\frac{P_p}{\sigma_p} \text{ cm}^2$$

where

P_p = design load, in kN, supported by the pillar as determined from 10.6

σ_p = permissible compressive stress, in N/mm^2

$$= \frac{f_p\,\sigma_s}{1 + 0{,}0051\sigma_s\, k_f \left(\frac{l_{ep}}{r}\right)^2} \text{ N/mm}^2$$

where

f_p = pillar location factor defined in Table 3.10.1

σ_s = specified minimum yield strength of the material, in N/mm^2

k_f = pillar end fixity factor
= 0,25 for full fixed/bracketed
= 0,50 for partially fixed
= 1,0 for free ended

r = least radius of gyration of pillar cross-section, in cm

$$= \sqrt{\frac{I_p}{A_p}} \text{ cm}$$

I_p = least moment of inertia of cross-section of pillar or stiffener/plate combination, in cm^4

l_{ep} = effective span of pillar, in metres, or bulkhead as defined in 10.2.

Table 3.10.1 Pillar location factors

Location	f_p
Supporting weather deck	0,50
Supporting vehicle deck	0,50
Supporting passenger deck	0,50
Supporting lower/inner deck	0,75
Supporting coachroof	0,75
Supporting deckhouse top	1,00

10.8 Maximum slenderness ratio

10.8.1 The slenderness ratio (l_{ep}/r) of pillars is not to be taken greater than 1,1. Where l_{ep} and r are as defined in 10.7.1. Pillars with slenderness ratio in excess of 1,1 may be accepted subject to special consideration on a case by case basis and provided that the remaining requirements of the Rules are complied with.

10.9 Pillars in tanks

10.9.1 In no circumstances are pillars to pass through tanks. Where loads are to be transmitted through tanks, pillars within the tanks are to be carefully aligned with the external pillars.

10.9.2 Pillars within tanks are, in general, to be of solid cross section. Where it is proposed to use hollow section pillars each case will be subject to special consideration and the scantlings as determined from the Rules may require to be increased dependent upon the material to be used, the fluid contained and the arrangement of the pillars. Hollow pillars are to be adequately drained and vented.

10.9.3 Where pillars within tanks may be subjected to tensile stresses due to hydrostatic pressure, the design is to provide sufficient welding to withstand the tensile load imposed.

10.9.4 Doubling plates at ends of pillars within tanks are not acceptable.

10.10 Pillar bulkheads

10.10.1 The stiffener/plate combination used in the determination of pillar bulkhead scantlings is to be that of a stiffener with an effective width of attached plating as determined from 1.11.

10.10.2 The cross-sectional area of the pillar bulkhead, A_{pb}, is to be determined in accordance with 10.7 using the design loading, P_{pb}, as follows:

$$P_{pb} = S_{bs}\, b_{pb}\, P_c + P_a \text{ kN}$$

where

P_{pb} = design load supported by the stiffener plate combination of the pillar bulkhead

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

S_{bs} = spacing, or mean spacing, of bulkheads or effective transverses/longitudinal stiffeners, in metres

b_{pb} = distance between centres of two adjacent spans of girders or transverses supported by the pillar bulkhead, in metres, and can be taken as the distance between pillar bulkhead stiffeners where the stiffeners at the top of the bulkhead effectively distributes the load evenly into the stiffeners.

10.10.3 The thickness of the bulkhead plating is in no case to be taken as less than 4 mm.

10.11 Direct calculations

10.11.1 As an alternative to 10.6, pillars may be designed on the basis of direct calculation. The method adopted and the stress levels proposed for the material of construction are to be submitted together with the calculations for consideration.

10.12 Fire aspects

10.12.1 Pillars and pillar bulkheads are to be suitably protected against fire, and, where necessary, be self-extinguishing or capable of resisting fire damage. All pillars are to comply with the requirements of Part 17.

10.13 Novel features

10.13.1 Where unusual or novel pillar designs are proposed that are unable to comply with the requirements of this Section, their design together with the direct calculations are to be submitted for special consideration.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to multi-hull craft of steel construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 Except as otherwise specified within this Chapter, the scantlings and arrangements of multi-hull craft are to be determined in accordance with the procedures described in, or required by Chapter 3 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hulls.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,3.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

L_R = Rule length of craft, in metres
s = stiffener spacing, in mm
t_p = plating thickness, in mm
k_s = high tensile steel factor
= $235/\sigma_s$
σ_s = specified minimum yield strength of the material, in N/mm^2.

1.5.2 **Bottom outboard**. For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom outboard shell is defined as the area of the hull between the outboard edge of the keel and the outer bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom outboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.3 **Bottom inboard**. For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom inboard shell is defined as the area of the hull between the inboard edge of the keel and the inner bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom inboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.4 **Cross-deck**. The cross-deck is defined as the structure which forms the bridge connection between any two adjacent hulls.

1.5.5 **Haunch**. The haunch is defined as the transition area between the cross-deck and the inboard side shell plating.

1.5.6 **Side inboard**. The side inboard is defined as the area between the bottom inboard shell and the wet-deck (or lower edge of the haunches, where fitted).

1.5.7 **Side outboard**. The side outboard is defined as the area between bottom outboard shell and the deck at side.

1.5.8 **Wet-deck**. The wet-deck is defined as the area between the upper edges of the side inboard plating (or upper edges of the haunches, where fitted).

■ *Section 2* Minimum thickness requirements

2.1 General

2.1.1 Unless otherwise specified in this Section, the requirements of Ch 3,2 are to be complied with.

2.1.2 The thickness of plating and stiffeners determined from the Rule requirements is in no case to be less than the appropriate minimum requirement given in Table 4.2.1 for craft type.

2.1.3 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy global strength requirements.

Table 4.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Catamaran	Multi-hull	Swath
Shell envelope Bottom shell plating	$\omega\sqrt{k_{ms}}\ (0{,}4\sqrt{L_R} + 2{,}0) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\ (0{,}4\sqrt{L_R} + 2{,}0) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\ (0{,}4\sqrt{L_R} + 2{,}0) \geq 3{,}5\omega$
Side shell plating	$\omega\sqrt{k_{ms}}\ (0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$
Wet-deck plating	$\omega\sqrt{k_{ms}}\ (0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$
Single bottom structure Centre girder web	$\omega\sqrt{k_{ms}}\ (0{,}8\sqrt{L_R} + 1{,}0) \geq 4{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}8\sqrt{L_R} + 1{,}0) \geq 4{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}8\sqrt{L_R} + 1{,}0) \geq 4{,}0\omega$
Floor webs	$\omega\sqrt{k_{ms}}\ (0{,}6\sqrt{L_R} + 0{,}8) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\ (0{,}6\sqrt{L_R} + 0{,}8) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\ (0{,}6\sqrt{L_R} + 0{,}8) \geq 3{,}5\omega$
Side girder webs	$\omega\sqrt{k_{ms}}\ (0{,}6\sqrt{L_R} + 0{,}8) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\ (0{,}6\sqrt{L_R} + 0{,}8) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\ (0{,}6\sqrt{L_R} + 0{,}8) \geq 3{,}5\omega$
Double bottom structure Centre girder:			
(1) Within $0{,}4L_R$ amidships	$\omega\sqrt{k_{ms}}\ (0{,}8\sqrt{L_R} + 1{,}0) \geq 4{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}8\sqrt{L_R} + 1{,}0) \geq 4{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}8\sqrt{L_R} + 1{,}0) \geq 4{,}0\omega$
(2) Outside $0{,}4L_R$ amidships	$\omega\sqrt{k_{ms}}\ (0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\omega$
Floors and side girders	$\omega\sqrt{k_{ms}}\ (0{,}6\sqrt{L_R} + 0{,}8) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\ (0{,}6\sqrt{L_R} + 0{,}8) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\ (0{,}6\sqrt{L_R} + 0{,}8) \geq 3{,}5\omega$
Inner bottom plating	$\omega\sqrt{k_{ms}}\ (0{,}5\sqrt{L_R} + 1{,}0) \geq 2{,}5\omega$	$\omega\sqrt{k_{ms}}\ (0{,}5\sqrt{L_R} + 1{,}0) \geq 2{,}5\omega$	$\omega\sqrt{k_{ms}}\ (0{,}5\sqrt{L_R} + 1{,}0) \geq 2{,}5\omega$
Bulkheads Watertight bulkhead plating	$\omega\sqrt{k_{ms}}\ (0{,}33\sqrt{L_R} + 1{,}0) \geq 2{,}5\omega$	$\omega\sqrt{k_{ms}}\ (0{,}33\sqrt{L_R} + 1{,}0) \geq 2{,}5\omega$	$\omega\sqrt{k_{ms}}\ (0{,}33\sqrt{L_R} + 1{,}0) \geq 2{,}5\omega$
Deep tank bulkhead plating	$\omega\sqrt{k_{ms}}\ (0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$
Deck plating and stiffeners Strength/Main deck plating	$\omega\sqrt{k_{ms}}\ (0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$
Lower deck/Inside deckhouse	$\omega\sqrt{k_{ms}}\ (0{,}18\sqrt{L_R} + 1{,}7) \geq 2{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}18\sqrt{L_R} + 1{,}7) \geq 2{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}18\sqrt{L_R} + 1{,}7) \geq 2{,}0\omega$
Superstructures and deckhouses Superstructure side plating	$\omega\sqrt{k_{ms}}\ (0{,}3\sqrt{L_R} + 1{,}0) \geq 2{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}3\sqrt{L_R} + 1{,}0) \geq 2{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}3\sqrt{L_R} + 1{,}0) \geq 2{,}0\omega$
Deckhouse front 1st tier	$\omega\sqrt{k_{ms}}\ (0{,}47\sqrt{L_R} + 1{,}5) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}47\sqrt{L_R} + 1{,}5) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}47\sqrt{L_R} + 1{,}5) \geq 3{,}0\omega$
Deckhouse front upper tiers	$\omega\sqrt{k_{ms}}\ (0{,}42\sqrt{L_R} + 1{,}3) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}42\sqrt{L_R} + 1{,}3) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}42\sqrt{L_R} + 1{,}3) \geq 3{,}0\omega$
Deckhouse aft	$\omega\sqrt{k_{ms}}\ (0{,}2\sqrt{L_R} + 0{,}6) \geq 2{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}2\sqrt{L_R} + 0{,}6) \geq 2{,}0\omega$	$\omega\sqrt{k_{ms}}\ (0{,}2\sqrt{L_R} + 0{,}6) \geq 2{,}0\omega$
Pillars Wall thickness of tubular pillars	$\omega\sqrt{k_{ms}}\ 0{,}05d_p$	$\omega\sqrt{k_{ms}}\ 0{,}05d_p$	$\omega\sqrt{k_{ms}}\ 0{,}05d_p$
Wall thickness of rectangular pillars	$\omega\sqrt{k_{ms}}\ 0{,}05b_p$	$\omega\sqrt{k_{ms}}\ 0{,}05b_p$	$\omega\sqrt{k_{ms}}\ 0{,}05b_p$
Symbols			
ω = service type factor as determined from Table 3.2.2 in Chapter 3 k_{ms} = $635/(\sigma_s + \sigma_u)$ σ_s = specified minimum yield strength of the material, in N/mm^2 σ_u = specified minimum ultimate tensile strength of the material, in N/mm^2 b_p = minimum breadth of cross section of hollow rectangular pillar, in mm d_p = outside diameter of tubular pillar, in mm			

Section 3
Shell envelope plating

3.1 General

3.1.1 Unless otherwise specified within this Section, the scantlings and arrangements for shell envelope plating are to be determined in accordance with the procedures described in, or as required by, Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in Section 2.

3.2 Keel plates

3.2.1 The breadth, b_k, and thickness, t_k, of plate keels are not to be taken as less than:

$$b_k = 5{,}0L_R + 250 \text{ mm}$$

$$t_k = \sqrt{k_s}\ 1{,}35L_R^{0{,}45} \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

3.2.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of plate keels are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by Ch 3,3.3.1 for the stem.

3.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

3.3 Bottom outboard

3.3.1 The thickness of the bottom outboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.3.2 For all craft types, the minimum bottom outboard shell thickness requirement given in Section 2 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.4 Bottom inboard

3.4.1 The thickness of the bottom inboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types, the minimum bottom inboard shell thickness requirement given in Section 2 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.5 Side outboard

3.5.1 The thickness of the side outboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.6 Side inboard

3.6.1 The thickness of the side inboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.7 Wet-deck

3.7.1 The thickness of the wet-deck plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.7.2 Additionally, the thickness of the wet-deck plating is in no case to be less than the thickness of the side inboard shell plating determined from 3.6.

3.7.3 The wet-deck plating on the underside of the cross-deck structure may require to be additionally protected, particularly where the air gap is small and there is a high risk of localised impact due to collision with floating debris, ice, etc., in the service area. In such cases the sheathing requirements given in Ch 3,2.4 are to be complied with.

3.8 Transom

3.8.1 The scantlings and arrangements of the stern or transom are to be not less than that required for the adjacent bottom inboard or side outboard structure as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.9 Haunch reinforcement (SWATH)

3.9.1 For craft above 40 m in Rule length, L_R, the stresses in the haunch area are to be derived using a two dimensional fine mesh finite element analysis. The model is to extend horizontally into the box structure and vertically into the strut structure. All discontinuities and cut-outs are to be modelled in order to determine shear stresses at critical locations and stresses for the determination of fatigue strength.

3.9.2 Due consideration is to be given to shear lag when determining the effective breadth of the attached plating.

3.10 Lower hull (SWATH)

3.10.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the thickness of the lower hull shell plating may be derived from an established method for shell analysis or recognised standard for pressure vessels using the design pressure loading from Pt 5, Ch 3,3.1 or Ch 4,3.1 as appropriate. Other loads considered significant for the scantling determination are to be taken into account. Modes of failure to be considered are buckling, frame collapse, inter-frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations are to be submitted for consideration.

3.11 Novel features

3.11.1 Where the Rules do not specifically define the requirements for plating elements with novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

■ *Section 4* Shell envelope framing

4.1 General

4.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for shell envelope framing are to be determined in accordance with the procedures described in, or as required by, Ch 3,3 for mono-hull craft using the pressures from Part 3 appropriate to multi-hulls.

4.1.2 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 Bottom outboard longitudinal stiffeners

4.2.1 Bottom outboard longitudinal stiffeners are to be supported by transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom outboard longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is proposed to terminate the bottom outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, all longitudinals are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.3 Bottom outboard longitudinal primary stiffeners

4.3.1 Bottom outboard longitudinal primary stiffeners are to be supported by deep transverse web frames, floors, bulkheads, or other primary structures, generally spaced not more than 4 m apart.

4.3.2 Bottom outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.4 Bottom outboard transverse stiffeners

4.4.1 Bottom outboard transverse stiffeners are defined as local stiffening members which support the bottom shell and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.5 Bottom outboard transverse frames

4.5.1 Bottom outboard transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.6 Bottom outboard transverse web frames

4.6.1 Bottom outboard transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is proposed to terminate the web frames in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.7 Bottom inboard longitudinal stiffeners

4.7.1 The scantlings and arrangements for bottom inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.2 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.8 Bottom inboard longitudinal primary stiffeners

4.8.1 The scantlings and arrangements for bottom inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.3 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.9 Bottom inboard transverse stiffeners

4.9.1 The scantlings and arrangements for bottom inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.4 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.10 Bottom inboard transverse frames

4.10.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.5 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.11 Bottom inboard transverse web frames

4.11.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.6 using the bottom inboard stiffening design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.12 Side outboard longitudinal stiffeners

4.12.1 The side outboard longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.12.2 Side outboard longitudinals are to be continuous through the supporting structures.

4.12.3 Where it is impracticable to comply with the requirements of 4.12.2, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.12.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.13 Side outboard longitudinal primary stiffeners

4.13.1 Side outboard longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.13.2 Side outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.13.3 Where it is impracticable to comply with the requirements of 4.13.2, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.13.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.14 Side outboard transverse stiffeners

4.14.1 Side outboard transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

4.14.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.15 Side outboard transverse frames

4.15.1 Side outboard transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.15.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.16 Side outboard transverse web frames

4.16.1 Side outboard transverse web frames are defined as primary stiffening members which support side shell longitudinals. They are to be continuous and substantially bracketed at their head and heel connections to deck beams and bottom web frames respectively.

4.16.2 Where it is impracticable to comply with the requirements of 4.16.1, or where it is proposed to terminate the side outboard longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.16.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.17 Side inboard longitudinal stiffeners

4.17.1 The scantlings and arrangements for side inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.12 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.18 Side inboard longitudinal primary stiffeners

4.18.1 The scantlings and arrangements for side inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.13 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.19 Side inboard transverse stiffeners

4.19.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.14 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.20 Side inboard transverse frames

4.20.1 The scantlings and arrangements for side inboard transverse frames are to be determined in accordance with the procedures described in 4.15 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.21 Side inboard transverse web frames

4.21.1 The scantlings and arrangements for side inboard transverse web frames are to be determined in accordance with the procedures described in 4.16 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.22 Wet-deck longitudinal stiffeners

4.22.1 The wet-deck longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.22.2 Wet-deck longitudinals are to be continuous through the supporting structures.

4.22.3 Where it is impracticable to comply with the requirements of 4.22.2, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.22.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.22.5 In no case are the scantlings and arrangements for the wet-deck longitudinal stiffeners to be taken as less than those required for the side inboard longitudinal stiffeners detailed in 4.17.

4.23 Wet-deck longitudinal primary stiffeners

4.23.1 Wet-deck longitudinal primary stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.23.2 Wet-deck longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.23.3 Where it is impracticable to comply with the requirements of 4.23.2, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.23.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.23.5 In no case are the scantlings and arrangements for the wet-deck longitudinal primary stiffeners to be taken as less than those required for the side inboard longitudinal primary stiffeners detailed in 4.18.

4.23.6 Additionally the requirements of Chapter 6 relating to global strength are to be complied with.

4.24 Wet-deck transverse stiffeners

4.24.1 Wet-deck transverse stiffeners are defined as local stiffening members supporting the wet-deck and may be continuous or intercostal.

4.24.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.24.3 In no case are the scantlings and arrangements for the wet-deck transverse stiffeners to be taken as less than those required for the side inboard transverse stiffeners detailed in 4.19.

4.25 Wet-deck transverse frames

4.25.1 Wet-deck transverse frames are defined as stiffening members which support the wet-deck. They are to be effectively continuous and bracketed at their end connections to side frames.

4.25.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.25.3 In no case are the scantlings and arrangements for the wet-deck transverse frames to be taken as less than those required for the side inboard transverse frames detailed in 4.20.

4.26 Wet-deck transverse web frames

4.26.1 Wet-deck transverse web frames are defined as primary stiffening members which support wet-deck longitudinals. They are to be continuous and substantially bracketed at their end connections to side transverse web frames.

4.26.2 Where it is impracticable to comply with the requirements of 4.26.1, or where it is proposed to terminate the wet-deck longitudinals in way of the bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.26.4 In no case are the scantlings and arrangements for the wet-deck transverse web frames to be taken as less than those required for the side inboard transverse web frames detailed in 4.21.

4.26.5 Primary transverse web frames that link the strength deck to the wet-deck structure and which carry the transverse global loading are additionally to comply with Ch 6,3.4.

4.26.6 Particular attention is to be taken to ensure that the continuity of transverse structural strength is maintained. All primary transverse members are to be continuous through the inboard side structure and integrated into transverse bulkheads or other primary structure within each hull (*see* Fig. 4.4.1). In the case of trimaran type craft the primary transverse members are to be continuous through the centre hull. Additionally the side inboard shell plating in way of the intersection is to be increased locally by not less than 50 per cent.

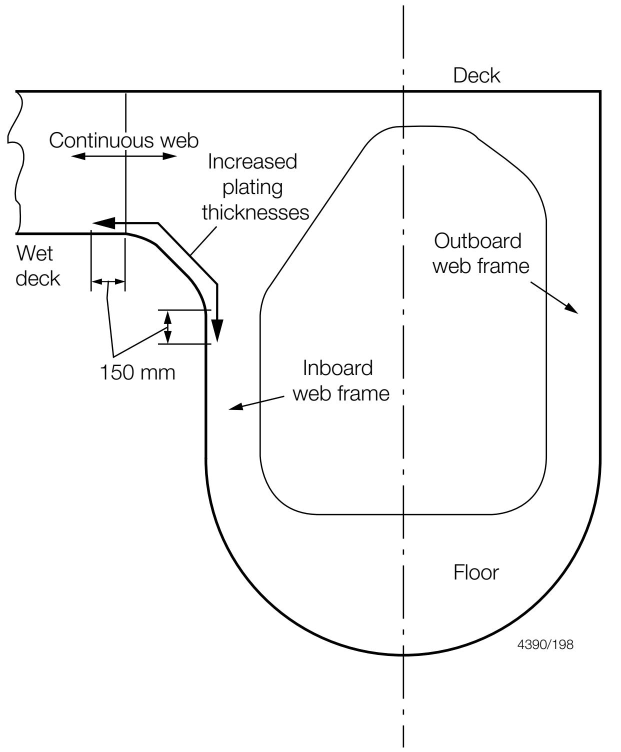


Fig. 4.4.1
End connection details, wet-deck structure

4.27 Lower hull (SWATH)

4.27.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the scantlings of the lower hull shell stiffening may be derived from an established method for stiffening analysis or recognised standard for pressure vessels using the design loading from Pt 5, Ch 4,4.1. Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations is to be submitted for consideration.

4.28 Scantlings of end brackets

4.28.1 The scantlings of end brackets in way of transverse web frames/crossdeck primary structure which carry transverse global loading, are to be as large as practicable and be additionally reinforced as necessary. The webs of deep brackets are to be stiffened as necessary to resist buckling, *see also* Ch 6,3.5.

■ *Section 5*

Single bottom structure and appendages

5.1 General

5.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for single bottom structure and appendages are to be determined in accordance with the procedures described in, or as required by, Ch 3,5 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

5.1.2 The thickness of single bottom structural members is in no case to be less than the appropriate minimum requirement given in Section 2.

5.2 Keel

5.2.1 The scantlings and arrangements of plate keels are to be in accordance with 3.2.

5.2.2 Where fitted, the cross-sectional area, A_{bk}, and thickness, t_{bk}, of bar keels are not, in general, be taken as less than:

$$A_{bk} = 0{,}75 L_R\, k_s \ \text{cm}^2$$

$$t_{bk} = \sqrt{k_s}\ (0{,}5 L_R + 2)\ \text{mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.3 Centre girder

5.3.1 Centreline girders are to be fitted throughout the length of each hull and are generally to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders may be formed with intercostal or continuous plate webs. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement are to be provided to maintain the continuity of structural strength.

5.3.3 The web depth of the centre girder is, in general, to be equal to the depth of the floors at the centreline as specified in 5.5.3.

5.3.4 The web thickness, t_w, of the centre girder is to be taken not less than:

$$t_w = \sqrt{k_s}\ (0,8\sqrt{L_R} + 1) \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.3.5 The face flat area, A_f, of the centre girder is to be not less than:

$$A_f = k_s\, 0,22 L_R \text{ cm}^2$$

where

L_R and k_s are as defined in 1.5.1.

5.3.6 The geometric section properties of the centre girder are to be in accordance with Ch 3,1.18.

5.3.7 The face flat area of the centre girder outside $0,5L_R$ may be 80 per cent of the value given in 5.3.5.

5.3.8 The face flat thickness is to be not less than the thickness of the web, t_w, as determined from 5.3.4.

5.3.9 The ratio of the width to thickness of the face flat is to be not less than eight but is not to exceed 16.

5.3.10 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 4,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 2 metres. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to be scarfed into the bottom structure forward and aft of the support at which they terminate, i.e. in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The web thickness, t_w, of side girder webs is to be taken as not less than:

$$t_w = \sqrt{(0,43 k_s L_R)} \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.4.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in 5.5.6 and 5.5.7.

5.4.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

5.4.5 Watertight side girders and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deep tanks as detailed in Ch 3,7.2 and Ch 3,7.4 respectively.

5.4.6 In the engineroom, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.5 Floors

5.5.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.5.2 In longitudinally framed craft, floors are in general to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.5.3 The overall depth, d_f, of floors at the centreline, is not to be taken as less than:

$$d_f = 6,2 L_R + 50 \text{ mm}$$

where

L_R is as defined in 1.5.1.

5.5.4 The web thickness of plate floors, t_w, is to be in accordance with Ch 3,1.18 and not less than:

$$t_w = \sqrt{k_s}\ \left(\frac{3,4 d_f}{1000} + 2,25\right)\left(\frac{s}{1000} + 0,5\right) \text{ mm}$$

where

d_f is to be determined from 5.5.3

k_s and s are as defined in 1.5.1.

5.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.6 The face flat area, A_f, of floors is not to be taken as less than:

$$A_f = 0,11 k_s L_R \text{ cm}^2$$

where

L_R and k_s are as defined in 1.5.1.

5.5.7 The face flat thickness, t_f, is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than eight but is not to exceed 16.

5.5.8 Additionally, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

5.5.9 Floors are in general to be continuous from side to side.

5.5.10 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.11 The floors in the aft peak are to extend over and provide efficient support to the stern tube(s) where applicable.

5.5.12 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in Ch 3,7.3 and Ch 3,7.5.

5.6 Floors in machinery space

5.6.1 The web thickness, t_w, of floors in machinery spaces is to be 1 mm greater than that required by 5.5.4.

5.6.2 The depth and mechanical strength properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The face flat area and web thickness of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength (*see also* Ch 3,4.12).

5.7 Forefoot and stem

5.7.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 3.2.

5.7.2 The forefoot and stem is to be additionally reinforced with floors.

5.7.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than:

$$A_{bs} = 0{,}6 k_s L_R \text{ cm}^2$$

where
k_s and L_R are as defined in 1.5.1.

■ Section 6
Double bottom structure

6.1 General

6.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for the double bottom structure are to be determined in accordance with the procedures described in, or as required by, Ch 3,6 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

6.1.2 The thickness of double bottom structural members is in no case to be less than the appropriate minimum requirement given in Section 2.

6.2 Keel

6.2.1 The scantlings of plate and bar keels are to comply with the requirements of 5.2.

6.3 Centreline girder

6.3.1 A centre girder is to be fitted throughout the length of the craft. The web thickness, t_w, is not to be less than that required by:

$$t_w = \sqrt{k_s}\,(0{,}06L_R + 3) \text{ mm within } 0{,}4L_R \text{ amidships}$$

$$= \sqrt{k_s}\,(0{,}06L_R + 2) \text{ mm at ends}$$

where
k_s and L_R are as defined in 1.5.1.

6.3.2 The geometric properties of the girder section are to be in accordance with Ch 3,1.18.

6.3.3 The overall web depth, d_w, of the centre girder is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the floor breadth does not exceed 4,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 4,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 2,0 m.

6.4.3 Side girders, where fitted, are to extend as far forward and aft as practicable and are in general to to be scarfed into the bottom structure forward and aft of the supporting bulkheads, deep floors or other primary transverse structure.

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 The geometric properties of the girder section are to be in accordance with Ch 3,1.18.

6.4.7 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness, t_w, of non-watertight plate floors is to be not less than:

$$t_w = \sqrt{k_s}\,(0{,}03L_R + 3{,}5) \text{ mm}$$

where
k_s and L_R are as defined in 1.5.1.

6.5.2 The geometric properties of the floor section are to be in accordance with Ch 3,1.18.

6.5.3 Additionally, the requirements of 4.6 for bottom inboard transverse web frames are to be complied with.

6.5.4 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.5 In longitudinally framed craft, plate floors are to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings, and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engineroom.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.6 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_w$ and a thickness of not less than t_w, where t_w is thickness of the plate floor as calculated in 6.5.1.

6.5.7 In transversely framed craft, plate floors are to be fitted at every frame in the engineroom, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Additional requirements for watertight floors

6.6.1 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in Ch 3,7.2 or Ch 3,7.4 respectively.

■ *Section 7* Bulkheads and deep tanks

7.1 General

7.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for bulkheads and deep tanks are to be determined in accordance with the procedures described in, or as required by Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

7.2 Longitudinal bulkheads within the cross-deck structure

7.2.1 Longitudinal bulkheads are to be fitted within the cross-deck structure to prevent cross flooding and the spread of flame and smoke. The minimum number of such bulkheads is to be two for catamarans and four for trimarans. Quadrimarans and other craft of novel configuration will be specially considered.

7.2.2 The scantlings and arrangements for cross-deck longitudinal bulkheads are to be determined in accordance with the procedures described in Ch 3,7.2 and Ch 3,7.3 for bulkheads in mono-hull craft.

7.2.3 In addition the requirements of 7.4 with regard to global strength are to be complied with.

7.3 Transverse bulkheads within the cross-deck structure

7.3.1 The scantlings of cross-deck transverse bulkheads are to be determined in accordance with the procedures described in Ch 3,7.2 and Ch 3,7.3 for bulkheads in mono-hull craft.

7.3.2 In addition the requirements of 7.4 in respect of global strength are to be complied with.

7.4 Additional strength required for global loading

7.4.1 Where transverse bulkheads or deep tank bulkheads within the cross-deck structure are to assist in resisting torsional or bending loads between the hulls, then the watertight/deep tank bulkheads may be required to be additionally stiffened and the plating or skin thicknesses may require to be increased. For hull girder strength requirements, *see* Ch 6,3.

7.4.2 Longitudinal bulkheads within the cross-deck structure that are to assist in maintaining the longitudinal strength of the craft are to satisfy both bulkhead/deep tank and longitudinal strength requirements. This may require additional stiffening and increase in plate thickness requirements. For hull girder strength requirements, *see* Ch 6,3.

7.4.3 Where longitudinal or transverse cross-deck bulkheads/deep tanks are to carry global loads, detailed calculations are to be submitted.

7.4.4 For longitudinal or transverse cross-deck members carrying global loads, consideration is to be given to stiffener arrangement, alignment, and continuity in order to maximise the rigidity and stiffness of the structure, in resisting the torsional/bending loads. Discontinuity of structural bulkheads is to be avoided.

7.5 Access

7.5.1 Access through the cross-deck structure may be permitted, provided that the global strength requirements are satisfied. Cut outs through the bulkhead are not to exceed 50 per cent of its depth, *see also* Ch 3,7.18.

7.5.2 Where the cross-deck structure acts as a watertight bulkhead pipe or cable runs through the watertight bulkheads are to be fitted with suitable watertight glands.

7.6 Local reinforcement

7.6.1 Bulkheads forming the cross-deck structure are to be suitably strengthened, if necessary, in way of deck girders and where subjected to concentrated loads.

7.7 Integral/deep tanks within cross-deck structure

7.7.1 Where the cross-deck structure forms the boundaries of deep tanks, the scantlings of these boundaries are to satisfy both deep tank and global strength requirements. For general and structural requirements for deep tanks, *see* Ch 3,7. For global considerations of strength, *see* Ch 6,3.

Section 8 Deck structures

8.1 General

8.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for deck structures are to be determined in accordance with the procedures described in, or as required by, Ch 3,8 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

8.2 Arrangements

8.2.1 Design loads to be applied for cross-deck scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 3.

8.2.2 For craft up to 50 m in Rule length, L_R, where the cross-deck is formed by transverse primary stiffeners or bulkheads, and subjected to global transverse loads in accordance with 8.2.1 the scantling requirements to satisfy the global loading condition are given in Ch 6,3.5.

8.2.3 Superstructures fitted on the cross-deck structures, on craft up to 50 m in Rule length, L_R, will, in general, be considered as non load carrying and are not to be included in the strength of the cross-deck. For designs where the superstructure is designed to absorb global loads, the requirements are given in Ch 6,3.2.

8.2.4 For craft more than 50 m in Rule length, L_R, global analysis is required to determine the response of the deck and superstructure as a system. Deck scantlings may then be derived for compliance with the requirements of Ch 6,3.

8.3 Cross-deck plating

8.3.1 The thickness of the cross-deck plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.3.2 The thickness of the cross-deck plating is in no case to be less than the appropriate minimum requirement given in Section 2.

8.3.3 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck, *see also* Part 4.

8.3.4 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.3.5 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* Ch 3,2.4.

8.4 Cross-deck stiffening

8.4.1 The Rule requirements for section modulus, inertia and web area for the cross-deck primary stiffeners are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

8.4.2 The Rule requirements for section modulus, inertia and web area of the strength/weather deck secondary stiffening are to be determined the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.4.3 The geometric properties of stiffener sections are to be in accordance with Ch 3,1.18.

8.4.4 For cases where there may be excessive rotations or deflections at supports or where the lateral pressure distribution is non-uniform, the above scantlings may require increasing appropriately.

8.4.5 Where stiffeners are subject to concentrated loads such as pillars, the concentrated loads are to be superimposed on the lateral pressure and strength calculations carried out to demonstrate compliance with the deflection and stress criteria given in Ch 7,2 and Ch 7,3.

8.4.6 Where stiffening members support plating of the extruded plank type, or the floating frame system is used, the plating is not to be included in the scantling derivation of the supporting structure.

8.4.7 Openings in the cross-deck for hatches, etc., are to comply with the requirements of Ch 3,8.11.

8.5 Novel features

8.5.1 Where the cross-deck structure is of unusual design, form or proportions, the scantlings are to be determined by direct calculation and a copy submitted for consideration.

■ *Section 9*
Superstructures, deckhouses, pillars and bulwarks

9.1 General

9.1.1 The scantlings and arrangements for superstructures, deckhouses and bulwarks are to be determined in accordance with the procedures described in, or as required by, Ch 3,9 for mono-hull craft.

9.1.2 The scantlings and arrangements for pillars and pillar bulkheads are to be determined in accordance with the procedures described in, or as required by, Ch 3,10 for mono-hull craft.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of steel construction as defined in Pt 1, Ch 1,1.

1.2 Symbols and definitions

1.2.1 The symbols and definitions used in this Chapter are defined below and in the appropriate Section:

s = stiffener spacing, in mm

k_s = higher tensile steel factor

= $235/\sigma_s$

σ_s = specified minimum yield strength of the material, in N/mm^2.

■ *Section 2* Special features

2.1 Water jet propulsion systems – Construction

2.1.1 The requirements for the construction and installation of water jet units apply irrespective of rated power.

2.1.2 Water jet ducts may be fabricated as an integral part of the hull structure, or as a bolted-in unit. In either case, detailed plans indicating dimensions, scantlings and materials of construction of the following are to be submitted in triplicate:

(a) Arrangement of the system including intended method of attachment to the hull and building-in, geometry of tunnel, shell opening, method of stiffening, reinforcement, etc.
(b) Shaft sealing arrangements.
(c) Details of any shafting support or guide vanes used in the water jet system.
(d) Details and arrangements of inspection ports, their closing appliances and sealing arrangement, etc.
(e) Details and arrangements of protection gratings and their attachments.

2.1.3 When submitting the plans requested in 2.1.2, details of the designers' loadings and their positions of application in the hull are to be submitted. These are to include maximum applied thrust, moments and tunnel pressures for which approval is sought.

2.1.4 All materials used in construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.5 Steels are to be of suitable grades in accordance with the requirements of Ch 2,2.

2.1.6 Irrespective of the material used, the strength and supporting structure of all tunnels are to be examined by direct calculation procedures which are to be submitted. In no case are the scantlings to be taken as less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

2.1.7 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of the guard are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

2.1.8 The inlet profile of the tunnel is to be so designed as to provide a smooth uptake of water over the range of craft operating trims and avoid significant separation of the flow into the rotating machinery.

2.1.9 Single or multiple water jet unit installations having a total rated power in excess of 500 kW are to be contained within their own watertight compartment. Other arrangements for maintaining watertight integrity may be specially considered depending on the size and installation layout.

2.1.10 For details of machinery requirements, *see* Pt 12, Ch 2.

2.2 Water jet propulsion systems – Installation

2.2.1 Standard units built for 'off the shelf' supply and which include the duct are to be installed strictly in accordance with the manufacturer's instructions, *see also* 2.1.4.

2.2.2 Integral water jet ducts are to be constructed in accordance with the manufacturer's requirements and the relevant plans submitted as required by 2.1.

2.2.3 Where load is transmitted into the transom and/or bottom shell, the thickness of the plating adjacent to the jet unit is to be increased. The increase in thickness is to be not less than 50 per cent of the calculated transom and bottom plating thicknesses respectively or 8 mm, whichever is the greater. Such reinforcement is to extend beyond the surrounding stiffening structure.

2.2.4 For 'bolted in' units, hull receiving rings are to be of a material compatible with the hull. Scantlings of the receiving rings are to be as required by the jet unit manufacturer and suitably edge prepared prior to welding in place. The receiving ring is to be installed using an approved welding procedure. Where a manufacturer's specification is not provided, full details are to be submitted.

2.2.5 Bolt sizes and spacings are to be specified by the manufacturer, and are to be of suitable marine grade, insulated as appropriate and locked by suitable means.

2.2.6 Where studs are proposed for the receiving ring(s), the remaining thickness below the depth of blind tap is to be not less than the bottom shell plating thickness plus 2 mm. Bottoms of all blind taps are to be free of sharp corners.

2.2.7 The use of approved alignment resins may be considered where accurate seating and faying surfaces are required. Details are to be submitted for consideration and approval.

2.2.8 Where a water jet unit forms an integral part of the hull structure, such units are to be installed using an approved weld procedure and in accordance with the manufacturer's instructions. Materials to be welded are to be of compatible specifications.

2.2.9 Water jet units transmitting thrust into the transom structure are to be supported by a system of radial, athwartship and vertical stiffening. Drawings are to be accompanied by a set of detailed structural calculations. Where complex installations are proposed, a finite element model may be submitted in lieu of direct calculations.

2.2.10 Water jet units transmitting thrust to a bottom shell connection or intermediate tunnel connection are to be supported by additional stiffening, the details of which are to be submitted.

2.3 Foil support arrangements

2.3.1 The materials and construction of the lifting surface will be considered on a case by case basis.

2.3.2 The design and performance of the lifting surface is outside the scope of classification. However, when submitting structural plans for the hull connection installation, the designer/Builder is to define:
(a) Operating mode, i.e. fully submerged or surface piercing.
(b) Maximum operational speed for which approval is sought.
(c) Maximum, direct, bending, shear and torque loads generated by the foil at the point of attachment(s).
(d) The type of profile or section used, e.g. N.A.C.A.
(e) Supply of lift/drag profile.
(f) If the foil is fixed, movable or retractable.
(g) If the foil is fitted with control surfaces.
(h) If the vertical leg(s) act as a rudder(s).
(j) If shaft liners are carried to the foils at which support arrangements are provided.
(k) If water intakes/scoops are fitted.
(l) If propulsion units are fitted.

2.3.3 The scantlings and arrangements of foils and their supporting structure will require to be specially considered in the following cases where:
(a) Propulsion units are incorporated within the foil.
(b) Foils carry shaft support arrangements.
(c) The foils are of novel design.

2.3.4 Where fully submerged foils are 'built-in' to the hull, the attachment area is to be contained within a watertight compartment the structural arrangements of 2.4 are to be complied with as appropriate.

2.3.5 Where foils are to be bolted to the structural foundation, calculations are to be submitted to demonstrate that the effect of loading arising from high speed impact, grounding, fouling, etc., is limited to failure of the bolted connection. In all cases the structural and watertight integrity of the craft is to be maintained.

2.3.6 Attachment points of foils are in all cases to be contained within a watertight compartment.

2.3.7 Foils attached by riveted means are in addition to comply with Ch 2,4.26.

2.3.8 Bow fairing doors fitted on forward retracting bow foils are to be weathertight and comply with Pt 3, Ch 4.

2.3.9 Aft bulkheads of bow foil compartments are to comply with the requirements for collision bulkheads as detailed in Ch 3,7.7.

2.3.10 Hydraulically operated retracting systems are to be equipped with low pressure and are to include a manual system of operation in the event of system failure.

2.3.11 A mechanical locking system is to be provided on retracting systems when the system is in both the operational and 'stowed' conditions.

2.4 Surface drive mountings

2.4.1 Transoms through which surface drive systems pass and which are required to carry thrust, significant weight, torque, moment, etc., are to be adequately reinforced.

2.4.2 The thickness of transom plating in way is to be not less than 1,5 times the thickness of the adjacent plating or as advised by the drive manufacturer, whichever is the greater.

2.4.3 Steering rams are to be mounted on suitably reinforced areas of plating supported by additional internal stiffening, details of which are to be submitted for consideration.

2.5 Sea inlet scoops

2.5.1 Sea inlet scoops may be integral with or an appendage to the hull.

2.5.2 Scoops are to be suitably positioned to minimise ventilation.

2.5.3 Suitable protective arrangements are to be provided to minimise the ingress of debris. The net area through the proposed arrangement is to be not less than twice that of the valves connected to the scoop. Provision is to be made for clearing the scoops by the use of suitable means and proposals are to be submitted.

2.5.4 Scoops are to be contained within a watertight compartment.

2.5.5 The plating thickness in way of integral scoops is to be not less than 1,5 times the thickness of the adjacent shell plating, with additional reinforcement at the leading edge.

2.5.6 For craft navigating in ice, the arrangements will be specially considered on an individual basis.

2.6 Crane support arrangements

2.6.1 Crane pedestals are to be efficiently supported and in general, are to be carried through the deck and satisfactorily scarfed into the surrounding structure. Alternatively, crane pedestals may comprise a foundation, in which case the foundation and its supporting structure are to be of substantial construction. Proposals for other support arrangements will be specially considered.

2.6.2 The pedestal or proposed arrangement is to be designed with respect to the worst possible combinations of loads resulting from the crane self weight, live load, wind and crane accelerations together with those resulting from the craft's heel and trim.

2.6.3 Stowage arrangements are to be taken into account when calculating the loads applied to the pedestal.

2.6.4 When submitting plans for the proposed foundation, the designer is to include design calculations covering the parameters indicated in 2.6.2.

2.6.5 Insert plates are to be incorporated in the deck plating in way of crane foundations. The thickness of the insert plates is to be as required by the designer's calculations but is in no case to be taken as less than 1,5 times the thickness of the adjacent attached plating.

2.6.6 All inserts are to have well radiused corners and be suitably edge prepared prior to welding. All welding in way is to be double continuous and full penetration where necessary. Tapers are to be not less than three to one.

2.7 Skirt attachment

2.7.1 The design and scantlings of the skirt are outside the scope of classification, however the designer/builder is to submit their proposals in respect of the attachment detail. The following supporting information is to be submitted:
(a) cushion pressure,
(b) calculations demonstrating that the effect of damage to the flexible membrane and/or the retaining section arising from high speed impact, grounding, fouling, etc., will not compromise the structural and watertight integrity of the craft.

2.7.2 The skirt is to be securely attached around its periphery and is to be suitably reinforced by the use of backing plates.

2.7.3 Where the skirt is retained by bolting, the retaining bars are to be as long as practicable with a fastener spacing of not more than 50 mm.

2.7.4 Where the design of the skirt is such that the flexible edge is retained by the use of a pre-formed channel, only the bolted hull connection of the preform to the hull structure is considered.

2.8 Trim tab arrangements

2.8.1 The shape, design and scantlings of the trim tabs are outside the scope of classification, however Lloyd's Register (hereinafter referred to as 'LR') is concerned with their attachment to the hull structure.

2.8.1 The designer/Builder is to submit the following:
(a) Detailed calculations indicating the maximum lift force generated by the tab for which acceptance is sought together with the corresponding speed and displacement.
(b) Details and calculations of the hull attachment.
(c) Details and calculations of the local internal reinforcement in way of the attachment.

2.8.3 Bearing materials used are to be of an approved type.

2.8.4 Fully submerged retractable trim tabs will be specially considered on a case by case basis.

2.9 Spray rails

2.9.1 Spray rails may be integrated into the hull structure or added in the form of an appendage on completion of the hull shell.

2.9.2 Where spray rails are integrated, they are to have a plating thickness not less than the adjacent bottom shell and additionally have a section modulus and inertia equivalent to that required for a longitudinal stiffener in the same position.

2.9.3 Where spray rails are added as an appendage, they are to be attached by double continuous welding and are additionally to comply with the strength requirements of 2.9.2.

2.9.4 Spray rails are to be supported by the internal stiffening arrangements and by additional local reinforcement as necessary.

2.9.5 In no case are the toes of spray rails to terminate on unsupported plating.

2.10 Other lifting surfaces

2.10.1 Other lifting surfaces not specifically covered by the Rules will be individually considered on the basis of submitted direct calculations.

2.10.2 Structure or hull shapes above the running waterline designed to generate aerodynamic lift may be individually considered on a case by case basis.

2.10.3 Aerodynamic, hydrodynamic and aero-hydrodynamic stability are outside the scope of classification and are subject to the approval of the National Administration concerned.

2.11 Propeller ducting

2.11.1 Where propellers are fitted within ducts/tunnels the plating thickness in way of the blades is to be increased by 50 per cent.

2.11.2 The tunnel wall in way of the propeller blades is to be additionally stiffened.

2.12 Ride control ducting and installation for Surface Effect Ships (SES)

2.12.1 Ducts penetrating the side inboard shell plating are to comply with the scantling requirements for side inboard structures, over their entire length in the appropriate material.

2.12.2 Ducts penetrating the wet-deck are to comply with the scantling requirements for wet-deck structures over their entire length in the appropriate material.

2.12.3 Open ends of ducts are to be fitted with a suitable protective grille.

2.12.4 The vent assembly, its design, construction and operation is outside the scope of classification and is the responsibility of the ride control system designer.

2.12.5 Details of the installation and securing arrangements of the vent valve assembly into the duct are to be submitted for approval.

■ *Section 3* Vehicle decks

3.1 General

3.1.1 These requirements are applicable to longitudinally or transversely framed craft intended for the carriage of wheeled vehicles, or where wheeled vehicles are to be used for cargo handling.

3.1.2 The deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, the hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.1.3 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Builder. These details are to include axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. The vehicle types and wheel loads for which the vehicle decks, including hatch covers where applicable, have been approved are to be included in the craft's documentation and contained in a notice displayed on each deck. For design purpose, the wheel loading is to be taken as not less than 3,0 kN.

3.1.4 The scantling requirements are based on structural strength and limitations on stress and deflection, with no allowance made for wear and tear. Local reinforcement is to be fitted as necessary, particularly in way of vehicle lanes and passenger routes.

3.1.5 The webs of vehicle deck stiffening members are in no cases to be scalloped.

3.2 Definitions

3.2.1 **Load Area**. The load area is defined as the footprint area of an individual wheel or the area enclosing a group of wheels when the distance between footprints is less than the smaller dimension of the individual prints.

3.3 Deck plating

3.3.1 The thickness, t_p, of vehicle deck plating is to be taken as not less than:

$$t_p = \frac{\alpha\, s}{1000\sqrt{k_s}} \text{ mm}$$

where

P_1 = corrected patch load, in tonnes, obtained from Table 5.3.1

α = thickness coefficient obtained from Fig. 5.3.1

s = secondary stiffener spacing, in mm

β_p = tyre print coefficient used in Fig. 5.3.1

$= \log_{10}\left(\frac{P_1\, k_s^2}{s^2} \times 10^7\right)$

s and k_s are as defined in 1.2.

Table 5.3.1 Deck plate thickness calculation

Symbols	Expression	
a, s, u, and v as defined in Fig. 5.3.1	$P_1 = \phi_1\ \phi_2\ \phi_3\ \lambda\ P_w$	
n = tyre correction factor as detailed in Table 5.3.2	$\phi_1 = \dfrac{2v_1 + 1{,}1s}{u_1 + 1{,}1s}$	$v_1 = v$, but $\leq s$ $u_1 = u$, but $\leq a$
P_1 = corrected patch load, in tonnes	$\phi_2 = 1{,}0$	for $u \leq (a - s)$
λ = dynamic magnification factor	$= \dfrac{1}{1{,}3 - \dfrac{0{,}3}{s}(a - u)}$	for $a \geq u > (a - s)$
P_w = load, in tonnes, on the tyre print. For closely spaced wheels the shaded area shown in Fig. 5.3.1 may be taken as the combined print	$= \dfrac{2v_1 + 1{,}1s}{u_1 + 1{,}1s}$	for $u > a$
f_1 = patch aspect ratio correction factor	$\phi_3 = 1{,}0$	for $v < s$
f_2 = panel aspect ratio correction factor	$= 0{,}6\ (s/v) + 0{,}4$	for $1{,}5 > (v/s) > 1{,}0$
f_3 = wide patch load factor	$= 1{,}2\ (s/v)$	for $(v/s) \geq 1{,}5$
	λ = 1,25 for craft operating in G1 = $(1 + 0{,}35n)$ for craft operating in G2 = $(1 + 0{,}42n)$ for craft operating in G3 = $(1 + 0{,}49n)$ for craft operating in G4 = $(1 + 0{,}56n)$ for craft operating in G5 = $(1 + 0{,}70n)$ for craft operating in G6 G1, G2, G3, G4, G5 and G6 as defined in Pt 1, Ch 2,3.5.5.	

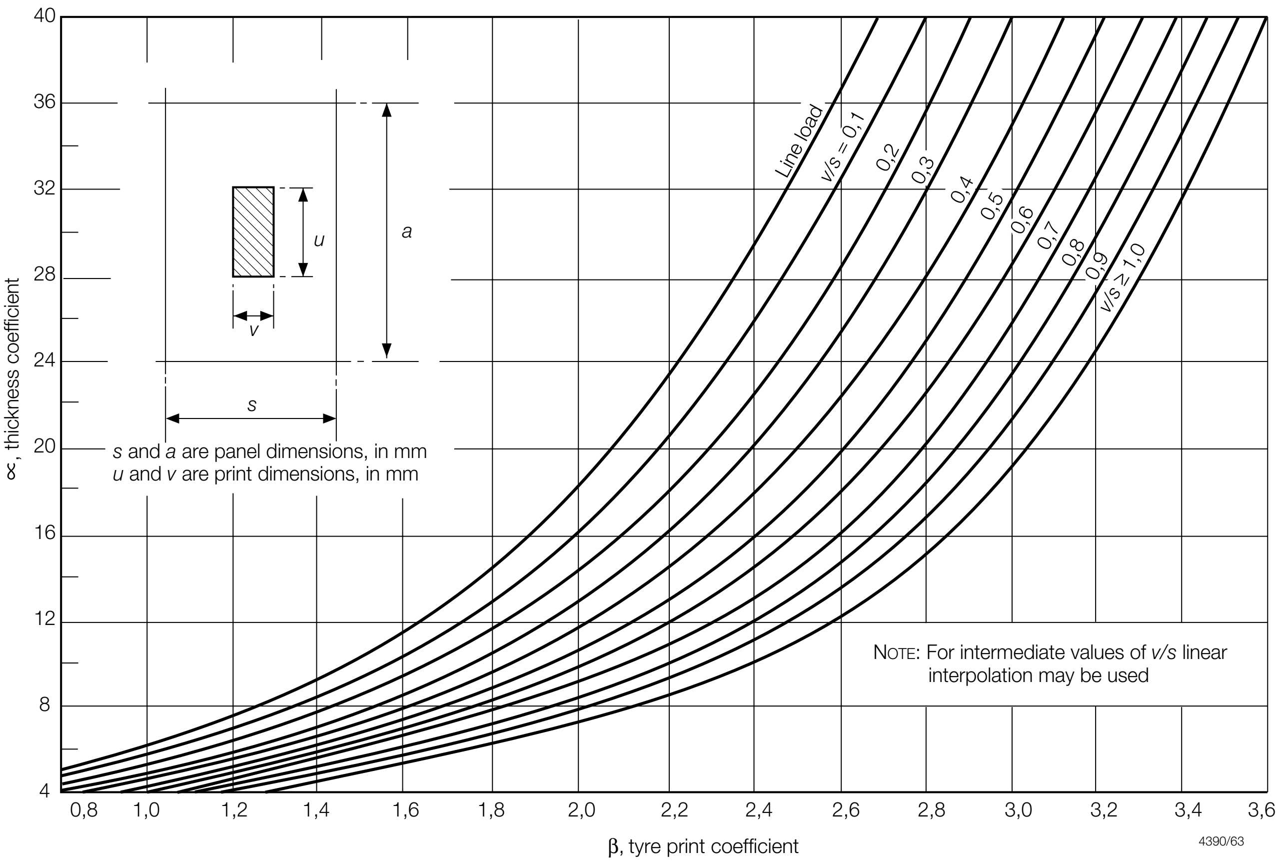


Fig. 5.3.1 Tyre print chart

3.4 Secondary stiffening

3.4.1 The scantlings of vehicle deck stiffeners are to be as required to satisfy the most severe arrangement of print wheel loads in conjunction with the cargo/weather deck design head.

3.4.2 The minimum requirements for section modulus, inertia and web area of vehicle deck secondary stiffeners subject to wheel loading are to be calculated in accordance with Table 5.3.3, *see also* Fig. 5.3.1 and Table 5.3.2.

Table 5.3.2 Tyre correction factor, *n*

Number of wheels in idealised patch	Pneumatic tyres correction factor, n	Solid rubber tyres correction factor, n
1	0,6	0,8
2 or more	0,75	0,9

3.4.3 When two or more load areas are located simultaneously on the same stiffener span, the scantling requirements are to be specially considered on the basis of direct calculation.

3.4.4 Where continuous secondary stiffeners pass through the webs of primary members, they are to be fully collared or lugged in way. The shear stresses at the connections are to be in compliance with Table 7.3.1 in Chapter 7.

3.5 Primary stiffening

3.5.1 The scantlings of vehicle deck primary girders and transverse web frames are to be determined on the basis of direct calculation in association with the limiting permissible stress and deflection criteria contained in Chapter 7.

3.6 Securing arrangements

3.6.1 Details of the connections to the hull of vehicle securing arrangements are to be submitted for approval.

3.6.2 Deck fittings in way of vehicle lanes are to be recessed.

3.6.3 The vehicle deck structure is to be of adequate strength for the upward forces imposed at fixed securing points. Local reinforcement is to be fitted as necessary.

Table 5.3.3 Secondary stiffener requirements

Scantling requirement	Load case $d \leq l$	Load case $d > l$
Section modulus (Z) (cm^3)	$Z = \left(\dfrac{P\,k_w\,(3l^2 - d^2)}{24\,l\,f_\sigma\,\sigma_s}\right) \times 10^3 + Z_{dk}$	$Z = \left(\dfrac{k_w\,P\,l^2}{10d\,f_\sigma\,\sigma_s}\right) \times 10^3 + Z_{dk}$
Inertia (I) (cm^4)	$I = \left(\dfrac{f_\delta\,P\,k_w\,(2l^3 - 2d^2\,l + d^3)}{384E\,l}\right) \times 10^5 + I_{dk}$	$I = \left(\dfrac{f_\delta\,k_w\,P\,l^3}{384E\,d}\right) \times 10^5 + I_{dk}$
Web area (A_w) (cm^2)	$A_w = \dfrac{10P\,k_w\,(m^3 - 2m^2 + 2)}{2f_\tau\,\tau_s} + A_{dk}$ where $m = d/l$	$A_w = \dfrac{k_w\,P\,l}{2d\,f_\tau\,\tau_s} + A_{dk}$

Symbols

P = maximum effective load per wheel or group of wheels, in kN
l = overall secondary stiffener length, in metres
s = stiffener spacing, in metres
d = dimension of load area parallel to stiffener axis, in metres
E = Young's Modulus of elasticity of material, in N/mm^2
w = dimension of load area perpendicular to stiffener axis, in metres
k_w = lateral loading factor
= 1 for $w \leq s$
= s/w for $w > s$
f_σ = limiting bending stress coefficient taken from Table 7.3.1 in Chapter 7
f_τ = limiting shear stress coefficient taken from Table 7.3.1 in Chapter 7
f_δ = limiting deflection coefficient taken from Table 7.2.1 in Chapter 7
σ_s = specified minimum yield strength of the material, in N/mm^2
τ_s = shear stress of material, in N/mm^2
= $\dfrac{\sigma_s}{\sqrt{3}}$
Z_{dk}, I_{dk}, A_{dk} = stiffener requirements for weather/cargo decks to be determined in accordance with Ch 3,8.7 and Ch 3,8.10 using the appropriate design head for weather/cargo. In no case is the head to be taken as less than 2 kN/m^2.

3.7 Access

3.7.1 Bow doors are to comply with the requirements of Section 4.

3.7.2 Where access to the vehicle deck is provided by side and stern doors, the doors are to have scantlings equivalent to the structure in which they are fitted, *see also* Pt 3, Ch 4,4.

3.7.3 Doors providing pedestrian access between vehicle decks and accommodation spaces are to be gastight, have scantlings equivalent to the surrounding structure and where applicable are to comply with the requirements of Part 17.

3.8 Hatch covers

3.8.1 The scantlings and arrangements of hatches and hatch covers located within vehicle decks are to be not less than that required by the Rules for the supporting structure in which such hatches are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

3.8.2 In no case, however, are the scantlings of plating and stiffeners to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.8.3 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of plating and stiffeners may be determined by direct calculations using a two dimensional grillage model. Copies of calculations are to be submitted.

3.9 Heavy and special loads

3.9.1 Where heavy or special loads are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered on the basis of submitted calculations.

3.9.2 Due account is to be taken of the acceleration levels due to craft motion as applicable to particular items of heavy mass such as vehicles, containers, pallets, etc.

3.10 Direct calculations

3.10.1 LR will consider direct calculations for the derivation of scantlings as an alternative to and equivalent to those derived by Rule requirements. The assumptions made and the calculation procedures used are to be submitted for appraisal in accordance with Pt 3, Ch 1,2.

■ *Section 4* **Bow doors**

4.1 Application

4.1.1 The requirements of this Section are applicable to the arrangement, strength and securing of bow doors, both the visor and the side opening type doors, and inner doors leading to a complete or long forward enclosed superstructure.

4.1.2 Other types of bow door will be specially considered.

4.2 General

4.2.1 The attention of Owners and Builders is drawn to the additional statutory regulations for bow doors that may be imposed by the National Authority.

4.2.2 Bow doors are to be situated above the freeboard deck. A watertight recess in the freeboard deck located forward of the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the freeboard deck.

4.2.3 An inner door is to be fitted. The inner door is to be part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, *see* Pt 3, Ch 2,4. A vehicle ramp may be arranged for this purpose, provided its position complies with Pt 3, Ch 2,4 and the ramp is weathertight over its complete length. In this case the upper part of the ramp higher than 2,3 m above the freeboard deck may extend forward of the limit specified in Pt 3, Ch 2,4. If this is not possible a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

4.2.4 Bow doors are to be fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors. Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

4.2.5 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in 4.2.3.

4.2.6 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in the stowed position.

4.3 Symbols and definitions

4.3.1 The symbols used in this Section are defined as follows:

A_s = area stiffener web, in cm^2

A_x = area, in m^2, of the transverse vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser, as shown in Fig. 5.4.2

A_y = area, in m^2, of the longitudinal vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser

A_z = area of the horizontal projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in m^2, whichever is the lesser, as shown in Fig. 5.4.2

a_{bv} = vertical distance, in metres, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Fig. 5.4.2

b_{bv} = horizontal distance, in metres, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in Fig. 5.4.2

c_{bv} = horizontal distance, in metres, from visor pivot to the centre of gravity of visor mass, as shown in Fig. 5.4.2

d_{bv} = Vertical distance, in metres, from bow door pivot to the centre of gravity of the bow door, as shown in Fig. 5.4.2

h = height of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in metres, whichever is the lesser, as shown in Fig. 5.4.1

K_s = higher tensile steel factor
= $235/\sigma_s$

l_d = length of the door at a height $h/2$ above the bottom of the door, in metres, as shown in Fig. 5.4.2

Q_{bd} = shear force, in kN, in the stiffener calculated by using uniformly distributed external pressure P_e as given in 4.5.1

W_{bv} = mass of the visor door, in tonnes

W = breadth of the door at a height $h/2$ above the bottom of the door, in metres, as shown in Fig. 5.4.2

σ = bending stress, in N/mm^2

σ_{eq} = equivalent stress, in N/mm^2
= $\sqrt{\sigma^2 + 3\tau^2}$

σ_s = specified minimum yield strength of the material, in N/mm^2

τ = shear stress, in N/mm^2.

4.3.2 **Locking device**. A device that locks a securing device in the closed position.

4.3.3 **Securing device**. A device used to keep the door closed by preventing it from rotating about its hinges.

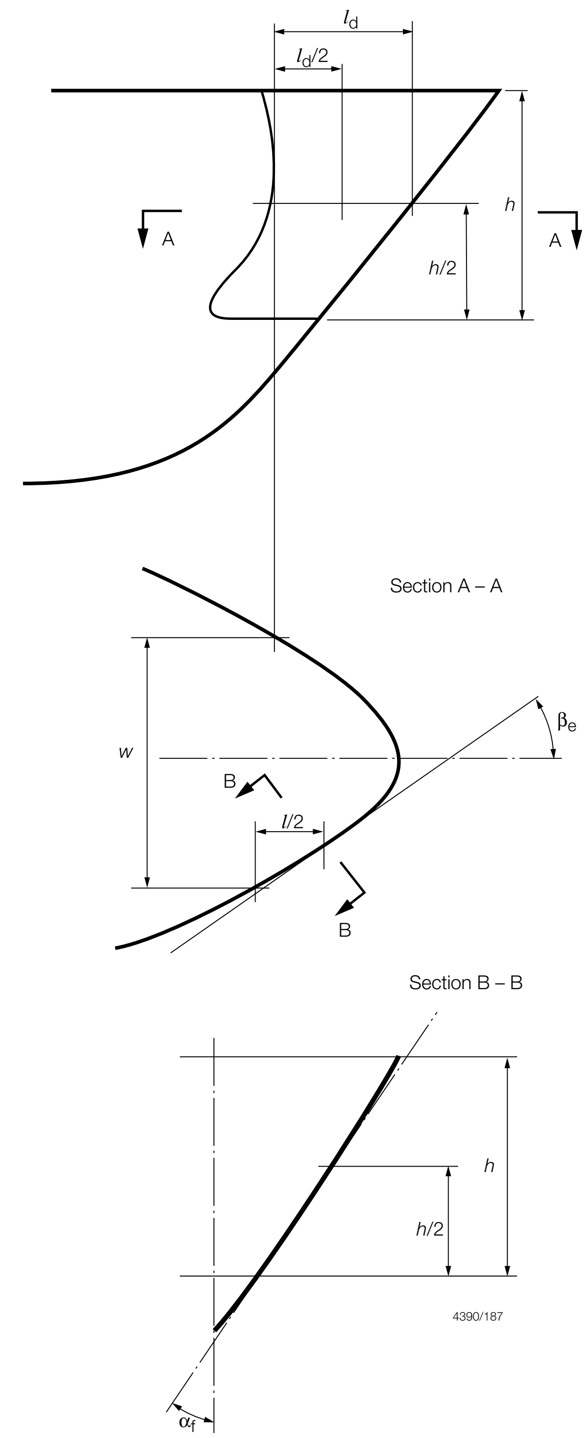


Fig. 5.4.1 Measurement of α_f and β_e

4.3.4 **Side-opening doors**. Side-opening doors are opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the craft. It is anticipated that side-opening doors are arranged in pairs.

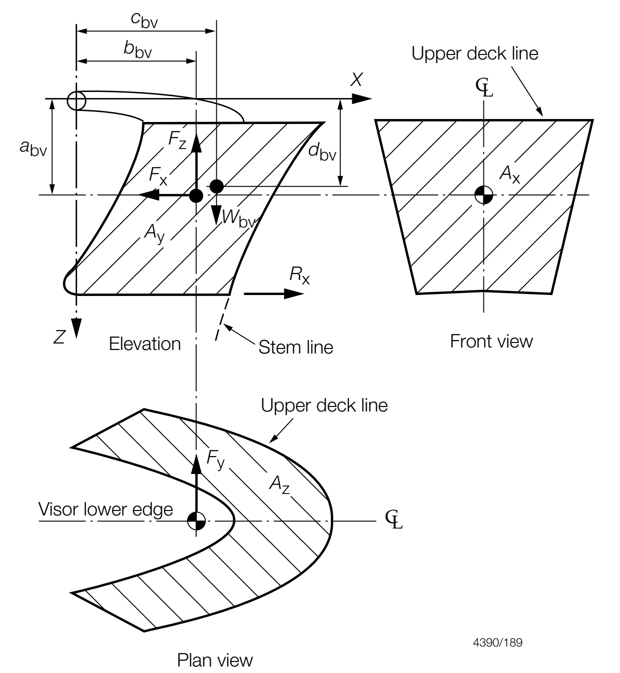


Fig. 5.4.2 Bow visor (upward hinging)

4.3.5 **Supporting device**. A device used to transmit external or internal loads from the door to a securing device and from the securing device to the craft's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the craft's structure.

4.3.6 **Visor doors**. Visor doors are opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary structure of the door by longitudinally arranged lifting arms.

4.4 Strength criteria

4.4.1 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be able to withstand the design loads defined in 4.5. The shear, bending and equivalent stresses are not to exceed $80/k_s$ N/mm^2, $120/k_s$ N/mm^2 and $150/k_s$ N/mm^2 respectively.

4.4.2 The buckling strength of primary members is to be verified as being adequate, *see* Ch 7,4.

4.4.3 For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed 80 per cent of the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.

4.4.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of steel bolts not carrying support forces is not to exceed $125/k_s$ N/mm^2.

4.5 Design loads

4.5.1 The design external pressure, P_e, for the determination of scantlings for primary members, securing and supporting devices of bow doors is to be taken not less than the following:

$$P_e = 2{,}75\lambda_G C_H (0{,}22 + 0{,}15\tan\alpha_f)$$
$$(0{,}4V_{max} \sin\beta_e + 0{,}6L_R^{0,5})^2 \quad \text{kN/m}^2$$

where

V_{max} = maximum speed, in knots, as defined in Pt 1, Ch 2, 2.2.10

L_R = Rule length of craft, in metres, as defined in Pt 3, Ch 1,6

λ_G = Service group factor for mono-hull craft, *see* Pt 1, Ch 2
= 0,5 for Group 1 and Group 2
= 0,6 for Group 3
= 0,8 for Group 4
= 1,0 for Group 5 and Group 6
For multi-hull craft, λ_G will be specially considered and may be reduced where the freeboard is significant

C_H = $0{,}0125L_R$ for $L_R < 80$ m
= 1,0 for $L_R \geq 80$ m

α_f = flare angle, in degrees, at the point to be considered, defined as the angle between a vertical line and the tangent to the side shell plating, measured in a vertical plane normal to the horizontal tangent to the shell plating, *see* Fig. 5.4.1

β_e = entry angle, in degrees, at the point to be considered, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane, *see* Fig. 5.4.1.

4.5.2 The design external forces, F_x, F_y and F_z, in kN, for the determination of scantlings of securing and supporting devices of bow doors are taken to be not less than $P_e A_x$, $P_e A_y$ and $P_e A_z$ respectively:
where

P_e is the external pressure, defined in 4.5.1, with the flare angle α_f, and the entry angle β_e, measured at the point on the bow door
$l_d/2$ aft of the stem line on the plane, and
$h/2$ above the bottom of the door, as shown in Fig. 5.4.1
A_x, A_y, A_z and h as defined in 4.3.1.

4.5.3 For bow doors, including bulwark, of unusual form or proportions, the areas used for the determination of the design values of external forces will be specially considered.

4.5.4 For visor doors the closing moment, M_y, under external loads, is to be taken as:

$$M_y = F_x a_{bv} + 10W_{bv} c_{bv} - F_z b_{bv} \quad \text{kNm}$$

where
W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in 4.3.1,
F_x and F_z are as defined in 4.5.2.

4.5.5 The lifting arms of a visor and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1,5 kN/m^2 is to be taken.

4.5.6 The design external pressure, in kN/m^2, for the determination of scantlings for primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of 0,45L_R and 10h_2, where h_2 is the distance, in m, from the load point to the top of the cargo space and L_R as defined in Pt 3, Ch 1,6.2.1.

4.5.7 The design internal pressure for the determination of scantlings for securing devices of inner doors is not to be taken less than 25 kN/m^2.

4.6 Scantlings of bow doors

4.6.1 The strength of bow doors is to be commensurate with that of the surrounding structure.

4.6.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed. For visor doors adequate strength for the opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the craft structure.

4.6.3 The thickness of the bow plating is not to be less than that required for the side shell plating, using bow door stiffener spacing, but in no case less than the minimum required thickness of fore end shell plating.

4.6.4 The section modulus of horizontal or vertical stiffeners is not to be less than that required for end framing. Consideration is to be given, where necessary, to differences in fixity between the craft's frames and bow doors stiffeners.

4.6.5 The stiffener webs are to have a net sectional area A_s, not less than:

$$A_s = \frac{23{,}5 Q_{bd}}{\sigma_s} \text{ cm}^2$$

where

A_s, Q_{bd} and σ_s are as defined in 4.3.1.

4.6.6 The bow door secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

4.6.7 The primary members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

4.6.8 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in 4.5.1 and permissible stresses given in 4.4.2.

4.7 Scantlings of inner doors

4.7.1 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure and permissible stresses given in 4.4.1. In general, formulae for simple beam theory may be applied.

4.7.2 Where inner doors also serve as a vehicle ramps, the scantlings are not to be less than those required for vehicle decks.

4.7.3 The distribution of forces acting on the securing and supporting devices is, in general, to be supported by direct calculations taking into account the flexibility of the structure and actual position and stiffness of the supports.

4.8 Securing and supporting of bow doors

4.8.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is, in general, not to exceed 3 mm. A means is to be provided for mechanically fixing the door in the open position.

4.8.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide load compression of the packing material are, in general, not to be included in the calculations called for in 4.8.8. The number of securing and supporting devices are, in general, to be the minimum practical whilst taking into account the requirements for redundant provision given in 4.8.9 and 4.8.10 and the available space for adequate support in the hull structure.

4.8.3 For opening outwards visor doors, the pivot arrangement is generally to be such that the visor is self-closing under external loads, that is $M_y > 0$. Moreover, the closing moment, M_y, as given in 4.5.4 is to be not less than:

$$M_y = 10 W_{bv}\, c_{bv} + 0{,}1(a_{bv}^2 + b_{bv}^2)^{0,5} \; (F_x^2 + F_z^2)^{0,5}$$

where

W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in 4.3.1, F_x and F_z are as defined in 4.5.2.

4.8.4 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in 4.4.1.

4.8.5 For **visor doors** the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door.

Case 1 F_x and F_z
Case 2 $0{,}7F_y$ acting on each side separately together with $0{,}7F_x$ and $0{,}7F_z$.

where
F_x, F_y and F_z are to be determined as indicated in 4.5.2 and applied at the centroid of projected areas.

4.8.6 For **side-opening doors** the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

Case 1 F_x , F_y and F_z acting on both doors.
Case 2 $0{,}7F_x$ and $0{,}7F_z$ acting on both doors and $0{,}7F_y$ acting on each door separately.

where
F_x, F_y and F_z are to be determined as indicated in 4.5.2 and applied at the centroid of projected areas.

4.8.7 The support forces as determined according to 4.8.5 and 4.8.6 are generally to give rise to a zero moment about the transverse axis through the centroid of the area A_x. For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be of the forward direction.

4.8.8 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

4.8.9 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable to withstand the reaction forces without exceeding by more than 20 per cent the permissible stresses as given in 4.4.1.

4.8.10 For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in 4.4.1. The opening moment, M_o, to be balanced by this reaction force, is not to be taken less than:

$$M_o = 10W_{bv}\, d_{bv} + 5A_x\, a_{bv} \text{ kNm}$$

where
W_{bv}, A_x, d_{bv} and a_{bv} as defined in 4.3.1.

4.8.11 For visor doors, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design force (F_z – $10W_{bv}$), in kN, within the permissible stresses given in 4.4.1.

4.8.12 All load transmitting elements in the design load path, from door through securing and supporting devices into the craft structure, including welded connections, are to be the same strength.

4.8.13 For side-opening doors, thrust bearing has to be provided in way of girder ends at the closing of the two leaves to prevent one leaf to shift towards the other one under effect of unsymmetrical pressure (*see* Fig. 5.4.3). Each part of the thrust bearing has to be kept secured on the other part by means of securing devices. Any other arrangements serving the same purpose are to be submitted for appraisal.

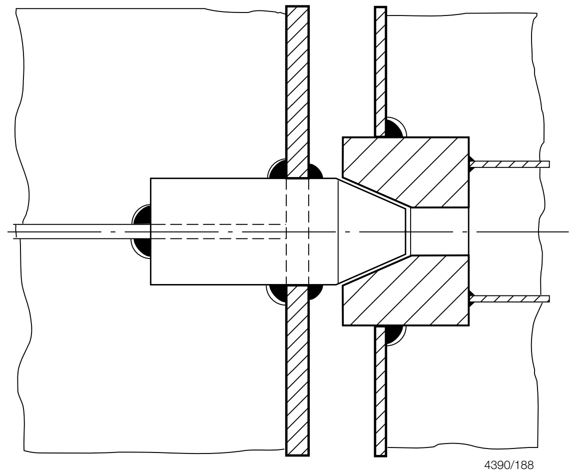


Fig. 5.4.3 Typical thrust bearing

4.9 Securing and locking arrangement

4.9.1 Securing devices are to be simple to operate and easily accessible. Securing devices are to be equipped with mechanical locking arrangements (self locking or separate arrangement), or be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

4.9.2 Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:
(a) the closing and opening of the doors; and
(b) associated securing and locking devices for every door.
Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorised persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

4.9.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position so that in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in closed position.

4.9.4 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. The indicator lights are to be provided with a permanent power supply, and arrangements are to be such that it is not possible to turn off these lights in service.

4.9.5 The indicator system is to be designed on the fail-safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors. The sensors of the indicator system are to be protected from water, ice formation and mechanical damage.

4.9.6 The indication panel on the navigation bridge is to be equipped with a mode selection function 'harbour/sea voyage', so arranged that audible alarm is given if the craft leaves harbour with the bow door or inner door not closed and with any of the securing devices not in the correct position.

4.9.7 A water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

4.9.8 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room. The system is to be able to monitor the position of doors and a sufficient number of their securing devices. Special consideration is to be given for lighting and contrasting colour of objects under surveillance.

4.9.9 A drainage system is to be arranged in the area between bow door and ramp, as well as in the area between the ramp and inner door where fitted. The system is to be equipped with an audible alarm function to the navigation bridge for water level in these areas exceeding 0,5 m above the car deck level.

4.10 Operating and Maintenance Manual

4.10.1 An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and contain necessary information on:

(a) main particulars and design drawings;
(b) service conditions, e.g. service area restrictions and acceptable clearances for supports;
(c) maintenance and function testing;
(d) register of inspections and repairs.

This manual is to be submitted for approval.

4.10.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

■ *Section 5* Movable decks

5.1 Classification

5.1.1 Movable decks other than those described in 5.1.2 are not a classification item, although consideration must be given to associated supporting structure. Where movable decks are fitted, it is recommended that they be based on the requirements of this Section.

5.1.2 At the Owner's or Builder's request, however, movable decks will be included as a classification item, and the class notation **Movable decks** will be entered in the *Register Book*. In such cases, all movable decks on board the ship are to comply with the requirements of this Section.

5.2 Arrangements and designs

5.2.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

5.2.2 Positive means of control are to be provided to secure decks in the lowered position.

5.2.3 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

5.2.4 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

5.2.5 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc., are to be submitted for consideration.

5.3 Loading

5.3.1 Details of the deck loading resulting from the proposed stowage arrangements of vehicles are to be supplied by the Shipbuilder. These details are to include the axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. For design purposes the wheel loading is to be taken as not less than 3,0 kN, *see* Section 3.

5.3.2 Where it is proposed also to use the decks for general cargo, the design loadings are to be submitted for consideration.

5.4 Scantling requirements

5.4.1 The scantlings and arrangements of removable decks are to be not less than those required by the Rules for the supporting structure in which the movable decks are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

5.5 Deflection

5.5.1 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during loading or unloading operations.

■ *Section 6* Helicopter landing areas

6.1 General

6.1.1 The landing area may be located on an appropriate area of the weather deck or on a platform specifically designed for this purpose and permanently connected to the craft structure.

6.1.2 The structure is to be designed to accommodate the largest helicopter type which it is intended to use. In general, the diameter of the landing area is to be not less than 1,25 times the rotor diameter.

6.1.3 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the craft.

6.1.4 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of helicopters to be used are also to be indicated. Details of the helicopter types to be used are to be included in the craft's documentation, and be contained in a notice displayed on the helicopter landing deck.

6.1.5 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

6.1.6 The requirements for fire protection, detection and extinction for yachts are to comply with Part 17. The requirements for other types of craft are outside the scope of classification and are therefore to comply with the requirements of the National Authority. Special consideration is to be given to the insulation standard if the space below the helicopter deck is a high fire-risk space.

6.2 Arrangements

6.2.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the helicopter, and is to be approached by a clear landing and take-off sector complying in extent with the applicable regulations.

6.2.2 The landing area is to be free of any projections above the level of the deck. Projections in the zone surrounding the landing area are to be kept below the heights permitted by the regulations.

6.2.3 Suitable arrangements are to be made to minimise the risk of personnel or machinery sliding off the landing area. A non-slip surface and anchoring devices, and in the case of independent platforms, safety nets, are to be provided.

6.2.4 Arrangements are to be made for drainage of the platform, including drainage of spilt fuel.

6.2.5 Details of arrangements for securing the helicopter to the deck are to be submitted for approval.

6.3 Landing area plating

6.3.1 The deck plate thickness, t_p, within the landing area is to be not less than:

$$t_p = \frac{\alpha s}{1000\sqrt{k_s}}$$

α = thickness coefficient obtained from Fig. 5.3.1
β_p = tyre print coefficient used in Fig. 5.3.1

$$= \log_{10}\left(\frac{P_1 k_s^2}{s^2} \times 10^7\right)$$

where
s and k_s are defined in 1.2.
The plating is to be designed for the emergency landing case taking

P_1 = 2,5 $\phi_1\ \phi_2\ \phi_3\ f\ \gamma\ P_w$ tonnes

where
ϕ_1, ϕ_2, ϕ_3 are to be determined from Table 5.3.1
f = 1,15 for landing decks over manned spaces, e.g. deckhouses, bridges, control rooms, etc.
= 1,0 elsewhere
P_h = the maximum all up weight of the helicopter, in tonnes
P_w = landing load, on the tyre print, in tonnes; P_w is to be taken as P_h divided equally between the two main undercarriages (for helicopters with single main rotor)
γ = a location factor given in Table 5.6.1

k_s is as defined in 1.2.

The tyre print dimensions specified by the manufacturer are to be used for the calculation. Where these are unknown it may be assumed that the print area is 300 mm x 300 mm and this assumption is to be indicated on the submitted plan.

Table 5.6.1 Location factor, γ

Location	γ
On decks forming part of the hull girder:	
(a) within 0,4L_R amidships	0,71 Values for intermediate locations are to be
(b) at the F.P. or A.P.	0,6 determined by interpolation
Elsewhere	0,6

6.3.2 For helicopters fitted with landing gear consisting of skids, the print dimensions specified by the manufacturer are to be used. Where these are unknown it may be assumed that the print consists of a 300 mm line load at each end of each skid, when applying Fig. 5.3.1.

6.4 Deck stiffening

6.4.1 The helicopter deck stiffening is to be designed for the load cases given in Table 5.6.2 with the helicopter being positioned so as to produce the most severe loading condition for each structural member under consideration.

6.4.2 The minimum requirements for section modulus, inertia and web area of secondary stiffeners are to be in accordance with Table 5.3.3.

6.4.3 For primary stiffening, and where a grillage arrangement is adopted, it is recommended that direct calculation procedures be used to determine the scantling requirements, in association with the limiting permissible stress criteria given in Chapter 7. A copy of the calculations is to be submitted for consideration.

■ *Section 7* Strengthening requirements for navigation in ice conditions

7.1 General

7.1.1 The strengthening requirements detailed in this Section are applicable to craft, other than those assigned the notation **HSC** and/or **LDC** (*see* Pt 1, Ch 2), intended for operation in light first year ice conditions in areas other than the northern Baltic corresponding to unbroken level ice of thickness not greater than 0,4 m.

7.1.2 Craft complying with the requirements of this Section, in addition to the requirements for sea-going service where applicable, will be eligible for the special features notation **Ice Class 1D**. Alternatively, a Special Duties Notation may be assigned indicating that the craft has been additionally strengthened for duties in ice (*see* Pt 1, Ch 2,3.8).

7.1.3 Craft designed to operate in ice conditions other than those detailed in 7.1.1 are to comply with Part 8 of the Rules for Ships.

7.1.4 The requirements of this Section are applicable to both longitudinally and transversely framed craft and concern the shell plating and framing in the forward region, the stem, sternframe, rudder and the steering gear.

7.1.5 The vertical extent of the ice strengthening is related to the ice light and load waterlines, which are defined in 7.2. The maximum and minimum Ice Class draughts at both the fore and aft ends will be stated on the Class Certificate.

7.1.6 The requirements of this Section assume that when approaching ice infested waters the craft's speed will be reduced appropriately. The vertical extent of ice strengthening for craft intended to operate in ice conditions at speeds exceeding 15 knots will be specially considered.

Table 5.6.2 Design load cases for deck stiffening and supporting structure

Loadcase	Loads (tonnes)			
	Landing area		Supporting structure (*see* Note 1)	
	UDL	Helicopter (*see* Note 2)	Self weight	Horizontal load (*see* Note 2)
(1) Overall distributed loading	2	–	–	–
(2) Helicopter emergency landing	0,2	2,5P_h f	W_h	0,5P_h
(3) Normal Usage	0,5	1,5P_h	W_h	0,5P_h + 0,5W_h

Symbols

P_h and f are as defined in 5.4.1.
UDL = Uniformly distributed vertical load over entire landing area, kN/m^2
W_h = structural weight of helicopter platform, in tonnes

NOTES
1. For the design of the supporting structure for helicopter platforms applicable self weight and horizontal loads are to be added to the landing area loads.
2. The helicopter is to be so positioned as to produce the most severe loading condition for each structural member under consideration.

7.1.7 The ballast capacity of propeller-driven craft is to be sufficient to give adequate propeller immersion in all ice navigating conditions without trimming the craft in such a manner that the actual waterline at the bow is below the ice light waterline. Ballast tanks situated above the ice light waterline and adjacent to the shell, which are intended to be used in ice navigating conditions, are to be provided with heating pipes.

7.2 Definitions

7.2.1 The Ice Load Waterline is that corresponding to the Fresh Water Summer Loadline.

7.2.2 The Ice Light Waterline is that corresponding to the lightest condition in which the craft is expected to navigate in ice.

7.2.3 The Ice Load Waterline and the Ice Light Waterline are to be indicated on the plans. For navigation in certain geographical areas, the relevant National Authority may require the maximum Ice Class draught to be marked on the craft in a specified manner.

7.2.4 The Main Ice Belt Zone extends vertically from 500 mm below the Ice Light Waterline to 400 mm above the Ice Load waterline and horizontally from the stem to $0{,}02L_R$ m aft of the point at which the deepest load waterline reaches its greatest breadth.

7.3 Powering of ice strengthened craft

7.3.1 Ice strengthened craft are assumed to be capable of developing sufficient thrust to permit continuous mode ice-breaking at a speed of at least five knots in ice having a thickness of 0,4 m and a snow cover of at least 0,3 m.

7.4 Shell plating

7.4.1 In way of the main ice belt zone, the thickness of the shell plating is to be determined by direct calculation. A copy of these calculations is to be submitted for consideration.

7.4.2 Changes in plating thicknesses in the longitudinal direction are to take place gradually.

7.4.3 Side scuttles are not to be situated in the ice belt.

7.4.4 If the weather deck in any part of the craft is situated below the upper limit of the ice belt, the bulwark is to be reinforced to the same degree as the shell plating in the main ice belt.

7.4.5 In general all welded seams and butts in way of the main ice belt are to be dressed smooth.

7.5 Shell framing requirements

7.5.1 Ice framing is to extend a minimum distance of 1000 mm above the Ice Load Waterline and 1600 mm below the Ice Light Waterline between the stem and $0{,}02L_R$ m aft of the point at which the deepest load waterline reaches its greatest breadth.

7.5.2 The web thickness of ice framing is not, in general, to be less than half that of the attached shell plating.

7.5.3 Ice frames are to be attached to the shell plating by double continuous welding and are not to be scalloped except at shell plating seams or butts. Air and drain holes are to be kept to a minimum.

7.5.4 Main and intermediate frames within the minimum extent of ice framing are to be efficiently supported to prevent tripping. The distance between anti-tripping supports is not to exceed 1000 mm.

7.5.5 The section modulus of an ice framing stiffening member is to be determined by direct calculation. A copy of these calculations is to be submitted for consideration.

7.5.6 Where transverse framing is adopted, ice stringers (primary longitudinal members supporting ice framing) are to be spaced not more than 1000 mm apart and are to have a section modulus not less than four times the section modulus of the transverse framing.

7.5.7 Where longitudinal framing is adopted, ice stringers need not be fitted.

7.6 Stem construction

7.6.1 Where a plate stem is fitted, the plate thickness is to be not less than 1,3 times that determined by Ch 3,3.3.

7.6.2 Where a bar stem is fitted, its cross-sectional area is to be not less than 1,25 times that determined by Ch 3,5.12.

7.7 Stern construction

7.7.1 A transom stern is not normally to extend below the ice load waterline. Where this cannot be avoided, the transom is to be kept as narrow as possible and the scantlings of plating and stiffeners are to be as required for the midcraft region.

7.8 Bossings and shaft struts

7.8.1 For craft with two or more propellers, shafting and sterntubes are generally to be enclosed within plated bossings. If detached supporting struts are necessary, their design, strengthening and attachment to the hull will be specially considered.

7.9 Rudder and steering arrangements

7.9.1 Rudder posts, rudder horns, sole pieces, rudder stocks and pintles are to be dimensioned in accordance with Pt 3, Ch 3,2. The speed used in the calculations is to be the service speed or 14 knots, whichever is the greater.

7.9.2 The thickness of rudder plating and webs is to be increased by 10 per cent over the requirements of Pt 3, Ch 3,2.

7.9.3 Due regard is to be paid to the method of securing the rudder in the centreline position when backing into ice. Where possible, rudder stoppers working on the blade or rudder head are to be fitted.

7.9.4 Where steering nozzles are fitted, the thickness of the shroud plating is to include an abrasion allowance of 2 mm.

7.9.5 The scantlings of the stock, pintles, gudgeon and sole pieces associated with the nozzle are to be increased on the basis given in 7.9.1. However, the diameter of the nozzle stock is to be not less than that calculated in the astern condition taking the astern speed as seven knots or the actual astern speed, whichever is the greater.

7.9.6 Nozzles with articulated flaps will be subject to special consideration.

Section 1
General

1.1 Application

1.1.1 The requirements for longitudinal and transverse global strength for mono-hull and multi-hull craft of steel construction, are contained within this Chapter. Due consideration is taken of the dynamic effects, where appropriate, in both the crest and trough wave landing conditions.

1.2 Symbols and definitions

1.2.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate sub-Section.

L_R = Rule length of the craft, in metres

B = moulded breadth of craft, *see* Pt 3, Ch 1,6.2.1, in metres (to be taken as the breadth of a single hull for multi-hull craft)

l = overall span length of stiffening member, in metres

l_e = effective span length of stiffening member, in metres

p = design pressure as appropriately given in Part 3, in kN/m^2

s = spacing of stiffener, in mm

t_p = thickness of plating, in mm

σ_s = specified minimum yield strength of the material, in N/mm^2

β = panel aspect ratio correction, *see* Ch 3,1.15

$\tau_s = \dfrac{\sigma_s}{\sqrt{3}}$

1.2.2 The strength deck is to be taken as follows:

(a) Where there is a complete upper deck the strength deck is the upper deck.

(b) Where the upper deck is stepped, as in the case of raised quarterdeck craft, the strength deck is stepped as shown in Fig. 6.1.1.

1.3 General

1.3.1 The additional pressures arising from the influence of the global loading are considered in the determination of the longitudinal strength requirements for local and secondary stiffening and bottom shell plating.

1.3.2 In general, the effective sectional area of continuous longitudinal strength members, after deduction of openings, is to be used for the calculation of midship section modulus.

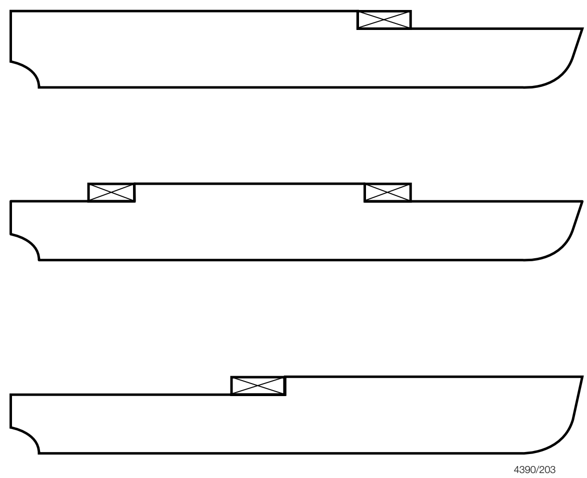


Fig. 6.1.1 Strength deck

1.3.3 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performances.

1.3.4 In general, superstructures or deckhouses will not be accepted as contributing to the global longitudinal or transverse strength of the craft. However, where it is proposed to include substantial, continuous stiffening members, special consideration will be given to their inclusion on submission of the designer's/Builder's calculations.

1.3.5 Where continuous deck longitudinals or deck girders are arranged above the strength deck, special consideration may be given to the inclusion of their sectional area in the calculation of the hull section modulus (Z). The lever is to be taken to a position corresponding to the depth of the longitudinal member above the moulded deckline at side amidships. Each such case will be individually considered.

1.3.6 Adequate transition brackets are to be fitted at the ends of effective continuous longitudinal strength members in the deck and bottom structures.

1.3.7 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section stiffness requirements determined from 2.2 are to be maintained within 0,4L_R amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the 0,4L_R part, bearing in mind the desire not to inhibit the craft's loading and operational flexibility.

1.4 Openings

1.4.1 Deck openings having a length in the fore and aft directions exceeding 0,1B m or a breadth exceeding 0,05B m are in all cases to be deducted from the sectional areas used in the section modulus calculation.

1.4.2 Deck openings smaller than stated in 1.4.1, including manholes, need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths (*see* 1.4.3) in one transverse section does not exceed 0,06 ($B_o - \Sigma\, b_o$).

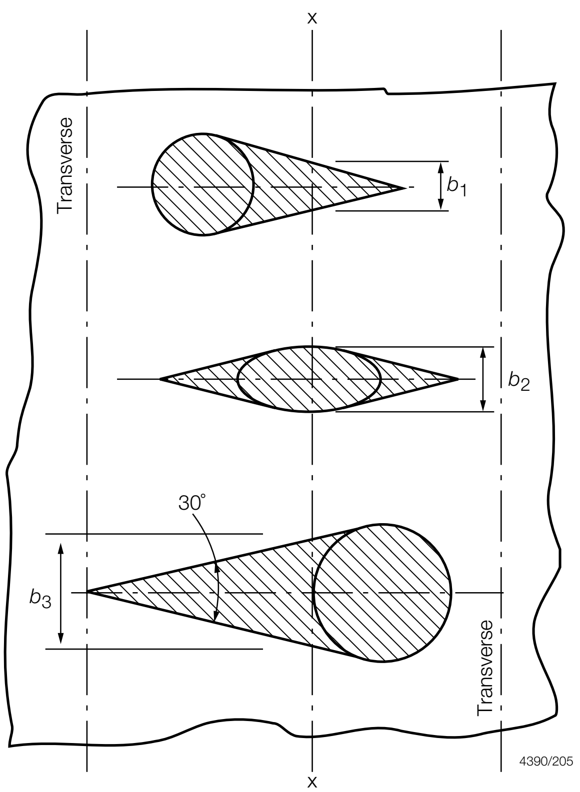
where

B_o = breadth of craft, in metres, at section considered

$\Sigma\, b_o$ = sum of breadths, in metres, of deductible openings

Where a large number of deck openings are proposed in any transverse space, special consideration will be required.

1.4.3 Where calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in Fig. 6.1.2. The shadow area is obtained by drawing two tangent lines to an opening angle of 30°. The section to be considered is to be perpendicular to the centreline of the ship and is to result in the maximum deduction in each transverse space.



Total equivalent breadth of small openings at xx = $b_1 + b_2 + b_3$

Fig. 6.1.2 Isolated openings

1.4.4 Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth or 75 mm, whichever is the lesser.

1.4.5 Openings are considered isolated if they are spaced not less than 1 m apart.

1.4.6 A reduction for drainage holes and scallops in beams and girders, etc., is not necessary so long as the original section stiffness at deck or keel is reduced by no more than 3,0 per cent.

1.5 Direct calculation procedure

1.5.1 In direct calculation procedures capable of deriving the wave induced loads on the craft, and hence the required modulus, account is to be taken of the craft's actual form and weight distribution.

1.5.2 Lloyd's Register's (hereinafter referred to as 'LR') direct calculation method involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval are normally to contain these three elements and produce similar and consistent results when compared with LR's methods.

1.6 Approved calculation systems

1.6.1 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from LR, calculations using the system for a particular craft may be submitted.

1.7 Information required

1.7.1 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR's standard format where appropriate:

(a) General arrangement and capacity plan or list, showing details of the volume and position of centre of gravity of all tanks and compartments.

(b) Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull. A lines plan and/or tables of offsets may also be required.

(c) Details of the calculated lightweight and its distribution.

(d) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions. It is recommended that this information be submitted in the form of a preliminary Loading Manual, to include the calculated still water and dynamic bending moments and shear forces.

1.8 Loading guidance information

1.8.1 Sufficient information is to be supplied to the Master of every craft to enable him to arrange loading in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

Section 2
Hull girder strength for mono-hull craft

2.1 General

2.1.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 50 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

2.1.2 For craft of ordinary hull form with a Rule length, L_R, less than 50 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the form, constructional arrangement and proposed loading.

2.1.3 Where the Rule length, L_R, of the craft exceeds 75 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

2.2 Bending strength

2.2.1 The effective geometric properties of the midship section are to be calculated directly from the dimensions of the section using only the effective material elements which contribute to the global longitudinal strength irrespective of the grades of steel incorporated in the construction. For the purposes of this analysis an element may be of deck plating, longitudinal girder, inner bottom, etc., or other continuous member.

2.2.2 The contribution that higher tensile steel makes to the global strength is based upon the strain in that material in relation to the allowable strain in mild steel. Therefore, the maximum permissible hull vertical bending stress, σ_p, for the design analysis is not to be taken greater than that determined from the following:

$$\sigma_{p\,(HTS)} = \sigma_{p\,(MS)}\,\frac{\overline{y}_{(HTS)}}{\overline{y}_{(MS)}}$$

where

σ_p is as defined in 2.2.3

$\overline{y}_{(HTS)}$ = the maximum distance, in metres, above or below the neutral axis of the hull cross-section to any effective higher tensile steel element contributing to global longitudinal strength

$\overline{y}_{(MS)}$ = the maximum distance, in metres, above or below the neutral axis of the hull cross-section to any effective mild steel element contributing to global longitudinal strength.

2.2.3 The longitudinal strength of craft with $\dfrac{V}{\sqrt{L_{WL}}} \geq 3{,}0$ is to satisfy both the following criteria:

$$\sigma_k + \sigma_l + \sigma_t < 1{,}2\sigma_P \text{ and}$$
$$\sigma_d < \sigma_P$$

where

σ_P = maximum permissible hull vertical bending stress, in N/mm^2 and is not to be taken greater than that determined from 2.2.2
= $f_{\sigma gH}$, σ_s or the value determined from 2.2.2, whichever is the lesser

$f_{\sigma gH}$ = limiting hull bending stress coefficient taken from Table 7.3.2 in Chapter 7

L_{WL} is as defined in Pt 3, Ch 1,6.2.5

σ_k, σ_l, σ_t and σ_d are given in Table 6.2.1

σ_s is as defined in 1.2.1.

Table 6.2.1 Longitudinal component stresses

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships	$\sigma_d = \dfrac{M_R}{1000Z_d}$
Hull girder bending stress at keel amidships	$\sigma_k = \dfrac{M_R}{1000Z_k}$
Actual stress in bottom longitudinals amidships due to design pressure load	$\sigma_l = \dfrac{p_s\, s\, l_e^2}{12Z_l}$
Actual stress in bottom plating amidships due to design pressure load	$\sigma_t = 0{,}34P_t\left(\dfrac{\beta\, s}{t_p}\right)^2 \times 10^{-3}$
Symbols and definitions	
M_R = design longitudinal midship bending moment, in kNm, given in Pt 5, Ch 5,5 p_s = additional effective pressure loading, in kN/m^2, on bottom longitudinals from global dynamic load model, given in Pt 5, Ch 5,2.6.3 P_t = additional effective pressure loading, in kN/m^2, on bottom plating from global dynamic load model, given in Pt 5, Ch 5,2.6.4 Z_d = actual section modulus at deck, in m^3 Z_k = actual section modulus at keel, in m^3 Z_l = maximum section modulus of bottom longitudinal stiffener, associated with plating, amidships, in cm^3 s, l_e, β and t_p are as defined in 1.2.	

2.2.4 The longitudinal strength of craft with $\dfrac{V}{\sqrt{L_{WL}}} < 3{,}0$ is to satisfy both the following criteria:

$$\sigma_k < \sigma_P$$
$$\sigma_d < \sigma_P$$

where

σ_P is as defined in 2.2.3

σ_k and σ_d are given in Table 6.2.1

L_{WL} is as defined in Pt 3, Ch 1,6.2.5.

2.3 Minimum hull section modulus

2.3.1 For patrol craft in Service Group G6, the hull midship modulus about the transverse neutral axis, at the deck or the keel, is to be not less than:

$Z_{min} = \eta_{HTS}\, L_f\, L_R^2\, B_{WL}\, (C_b + 0{,}7) \times 10^{-6}$ m^3

where

η_{HTS} is as defined in Ch 2,2.4.3

L_R and C_b are as given in Pt 5, Ch 2,2.2.2

C_b to be taken not less than 0,6

L_f is as given in Pt 5, Ch 5,2.2.2

B_{WL} = maximum breadth at the design waterline, in metres.

2.4 Shear strength

2.4.1 The shear strength of the craft at any position along its length is to satisfy the following criterion:

$$\frac{Q_R}{A_\tau} 10^{-3} \le \tau_p$$

where

Q_R = design hull shear force at any section along the Rule length, L_R, in kN determined from Pt 5, Ch 5,5

A_τ = shear area of transverse section, in m^2, is to be taken as the effective net sectional area of the shell plating and longitudinal bulkheads after deductions for openings. For longitudinal strength members which are inclined to the vertical, the area of the member to be included in the calculation is to be based on the area projected onto the vertical plane, *see* Fig. 6.2.1

τ_p = maximum permissible mean shear stress, in N/mm^2
= $f_{\tau gH}\, \tau_s$

$f_{\tau gH}$ = limiting hull shear stress coefficient taken from Table 7.3.2 in Chapter 7

τ_s is as defined in 1.2.1.

2.5 Torsional strength

2.5.1 Torsional stresses are typically small for mono hulls of ordinary form of Rule length, L_R, less than 75 m and can generally be ignored.

2.5.2 The calculation of torsional stresses and/or deflections may be required when considering craft with large deck openings, unusual form or proportions. Calculations may in general be required to be carried out using a direct calculation procedure. Such calculations are to be submitted in accordance with 1.5.

2.6 Superstructures global strength

2.6.1 The effectiveness of the superstructure in absorbing hull girder bending loads is to be established where the first tier of the superstructure extends within 0,4*L* amidships and where:

$$l_1 > b_1 + 3h_1$$

where

l_1 = length of first tier, in metres

b_1 = breadth of first tier, in metres

h_1 = 'tween deck height of first tier, in metres.

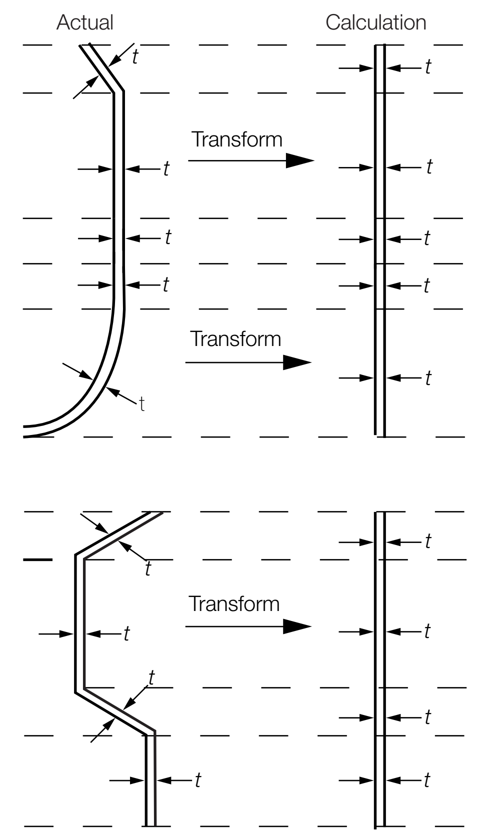


Fig 6.2.1 Effective shear area

2.6.2 For superstructures with one or two tiers extending outboard to the craft's side shell, the effectiveness in absorbing hull girder bending loads in the uppermost effective tier may be assessed by the following factor:

$$\eta_s = 7\,[(\varepsilon - 5)\,\gamma^4 + 94\,(5 - \varepsilon)\,\gamma^3 + 2800\,(\varepsilon - 5{,}8)\,\gamma^2 + 27660\,(9 - \varepsilon)\,\gamma]\, f(\lambda, N) \times 10^{-7}$$

where

$f(\lambda, N = 1) = 1$

$f(\lambda, N = 2) = 0{,}90\lambda^3 - 2{,}17\lambda^2 + 1{,}73\lambda + 0{,}50$

and

N = 1 if $l_2 < 0{,}7 l_1$
= 2 if $l_2 \ge 0{,}7 l_1$

$\lambda = \dfrac{l_w}{L_R}$ or 1, whichever is less

$\varepsilon = \dfrac{b_1}{h_1}$ or 5, whichever is less

$\gamma = \dfrac{l_w}{h_1}$ or 25, whichever is less

$l_w = l_1$ for $N = 1$

$= \dfrac{(2l_1 + l_2)}{3}$ for $N = 2$

L_R = as defined in 1.2.1, in metres

l_1, b_1, h_1 = as defined in 2.5.1, in metres

l_2 = length of second tier, in metres.

2.6.3 The hull girder compressive bending stress σ_L, in the uppermost effective tier at side may be derived according to the following formula:

$$\sigma_L = \eta_s \frac{M_R}{1000 Z_{100}} \text{ N/mm}^2$$

where

M_R = hull girder bending moment at midships due to sagging as determined in Pt 5, Ch 5,5, in kNm

Z_{100} = section modulus at uppermost effective tier of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^3

η_s = as defined in 2.6.2.

2.6.4 The compressive stress, σ_L, in the uppermost effective tier at side is to be checked against buckling in accordance with Ch 7,4.

2.6.5 The uppermost effective tier may need to fulfil the requirements for strength deck when the following applies:

$$\eta_s > \left(1 + \frac{Z_0\, h}{I_{100}}\right)^{-1}$$

where

η_s = as defined in 2.6.2

Z_0 = section modulus of hull only at hull upper deck, in m^3

I_{100} = moment of inertia of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^4

h = height from hull upper deck to uppermost effective tier, in metres.

■ *Section 3* Additional hull girder strength requirements for multi-hull craft

3.1 General

3.1.1 Except as otherwise specified within this Section, the global strength requirements for multi-hull craft are to comply with Section 2.

3.1.2 Longitudinal strength calculations are to be submitted for all craft with a length, L_R, exceeding 40 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

3.1.3 For craft of ordinary hull form length with a Rule length, L_R, less than 40 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the proposed loading.

3.1.4 Where the length, L_R, of the craft exceeds 60 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

3.1.5 The strength deck plating in way of the cross-deck structure, the wet-deck plating, longitudinal bulkheads and girders, and other continuous members may be included in the determination of the midship section stiffness.

3.1.6 Special consideration will be given to the global strength requirements for craft with more than two hulls linked by cross-deck structure.

3.2 Hull longitudinal bending strength

3.2.1 The requirements of 2.2 are in general to be complied with, using the appropriate design bending moment and effective pressure loadings applicable to multi-hull craft, as determined from Pt 5, Ch 5,5.

3.3 Hull shear strength

3.3.1 The requirements of 2.3 are to be complied with so far as they are applicable.

3.4 Torsional strength

3.4.1 Where a craft is of unusual form or novel construction, or at the discretion of LR, the torsional stress is to be determined by direct calculation methods using the twin hull torsional connecting moment as defined in Pt 5, Ch 5,5. Such calculations are to be submitted in accordance with 1.5.

3.5 Strength of cross-deck structures

3.5.1 Design loads to be applied for scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 5.

3.5.2 The primary stiffening members of the cross-deck structure are to provide sufficient strength to satisfy the stress criteria given in Table 6.3.1.

3.5.3 The component nominal stresses may be determined in accordance with Table 6.3.2 in the case where the cross-deck is formed by transverse primary stiffeners or bulkheads and the following assumptions are taken:

(a) The cross-deck is symmetrical forward and aft of a transverse axis at its half length.

(b) Primary stiffeners having the same scantlings and spacing.

3.5.4 Other cross-deck designs subjected to global transverse loads will require a two-dimensional grillage analysis to be performed to demonstrate compliance with 3.5.2.

Table 6.3.1 Primary member stress criteria

Stress type	Component stresses	Allowable stress level (N/mm^2)
Total direct stress, σ_P	$\sigma_P = \sigma_{MB} + \sigma_{MT} + \sigma_d$	$f_{\sigma gV}\ \sigma_s$
Total shear stress, τ_P	$\tau_P = \tau_T + \tau_{MBT} + \tau_{MT}$	$f_{\tau gV}\ \tau_s$
Equivalent stress, σ_{eq}	$\sigma_{eq} = \sqrt{\sigma^2 + 3\tau^2}$	$1{,}2 f_{\sigma eg}\ \sigma_s$
Symbols and definitions		
σ_{MB}, σ_{MT}, τ_T, τ_{MBT} σ_d, and τ_{MT} are component stresses, in N/mm^2, to be taken from Table 6.3.2 $f_{\sigma gV}$, $f_{\tau gV}$ and $f_{\sigma eg}$ are limiting stress coefficients for cross-deck structures to be taken from Table 7.3.2 in Chapter 7 σ_s and τ_s are defined in 1.2		

Table 6.3.2 Cross-deck component stresses for designs complying with 3.5.3

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships, *see* Table 6.2.1	$\sigma_d = f_{MR}\dfrac{M_R}{1000Z_d}$
Stress induced by the transverse bending moment M_B, as defined in Pt 5, Ch 5,5	$\sigma_{MB} = f_{MB}\dfrac{M_B}{nZ}\ 10^3$
Stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\sigma_{MT} = f_{MT}\dfrac{3x_H\ M_T}{n\ (n+1)\ s_p\ Z}\ 10^3$
Shear stress induced by the vertical shear force Q_T, as defined in Pt 5, Ch 5,5	$\tau_T = f_{MB}\dfrac{5Q_T}{n\ A_w}$
Bending shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\tau_{MBT} = f_{MT}\dfrac{60M_T}{n\ (n+1)\ s_p\ A_w}$
Shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\tau_{MT} = f_{MT}\dfrac{46\kappa\ x_H^2\ M_T}{n\ (n^2+1)\ s_p^2\ I_y}\ 10^3$
Symbols and definitions	
Q_T = vertical shear force, in kN, as determined from Pt 5, Ch 5,5 M_B = transverse bending moment in kNm, as determined from Pt 5, Ch 5,5 M_T = torsional moment in kNm, as determined from Pt 5, Ch 5,5 n = total number of transverse primary stiffeners or bulkheads A_W = stiffener web area, cm^2 Z = primary stiffeners section modulus, in cm^3 s_p = stiffener spacing, in metres I_y = moment of inertia of stiffener, cm^4 x_H = transverse distance between the centre of the two hulls, in metres κ = t_f, for symmetrical I-section, in mm = $b_b\ h/(b_b + h)$, for constant thickness box sections, in mm σ_{MB} = stress induced by the transverse bending moment M_B, as defined in Pt 5, Ch 5,5, in N/mm^2 σ_{MT} = stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2 τ_T = shear stress induced by the vertical shear force Q_T, as defined in Pt 5, Ch 5,5, in N/mm^2 τ_{MBT} = bending shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2 τ_{MT} = shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2 t_f = face plate thickness, in mm b_b = breadth of box section, in mm h_b = height of box section, in mm f_{MR}, f_{MB} and f_{MT} are load combination factors reflecting the portions of each component global design load, M_R, Q_T, M_B and M_T, corresponding to the most severe load combinations, The most severe load combinations are the combinations of loads resulting in the maximum bending, shear and effective stress, respectively. The assessment of these load combinations need to take due consideration for the component load magnitude variation with wave heading and also the phasing in time between them. Generally, f_{MR}, f_{MB}, and f_{MT} are to be taken as indicated in Table 6.3.3.	

Table 6.3.3 Load combination factors

Heading	Factors		
	f_{MB}	f_{MR}	f_{MT}
Head sea	0,1	1,0	0,1
Beam sea	1,0	0,1	0,2
Quartering sea	0,1	0,4	1,0

3.5.5 Section properties are to be calculated using an effective breadth of plating to be determined in accordance with Ch 3,1.11.

3.5.6 Where primary stiffening members support areas of plating of the extruded plank type, or the floating frame system is used, the effect of the plating attached to the secondary stiffening members is to be ignored when determining the global section modulus requirements.

3.6 Grillage structures

3.6.1 For complex girder systems, a complete structural analysis using numerical methods may be required to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

3.6.2 In general, the transverse and vertical girders, bottom and side structures, bridge structure, deck structures and any other parts of the craft which LR considers critical to the craft's structural integrity are to be included in the numerical modelling of the craft.

3.7 Analysis techniques

3.7.1 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

3.7.2 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

3.7.3 Analysis of the cross-deck structures with regard to impact loads due to slamming may have to be carried out using advanced structural analysis techniques.

Section

Section 1 General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of steel construction as defined in Ch 1,1.1.

1.2 General

1.2.1 The failure modes criteria contained within this Chapter are to be used in the formulae from the preceding Chapters to determine the scantling requirements. In addition, they are to be used when direct calculation methods are proposed as an alternative.

1.3 Symbols and definitions

1.3.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate Section.

1.4 Direct calculations

1.4.1 Where direct calculations are proposed, the requirements of Pt 3, Ch 1,2 are to be complied with.

1.4.2 In addition, with the agreement of Lloyd's Register (hereinafter referred to as 'LR'), tests may be conducted to demonstrate the actual response of the structure and the results verified against the failure mode criteria in this Chapter.

Section 2 Deflection control

2.1 General

2.1.1 The limiting deflection requirements for plate panels and stiffening members are given in terms of limiting deflection coefficient, *see* Table 7.2.1. The coefficient equates to a span/deflection ratio, f_δ, in consistent units.

Table 7.2.1 Limiting deflection ratio

Item	Deflection ratio, f_δ
Bottom structure:	
• secondary stiffening	800
• primary girders and web frames	1000
Side structure:	
• secondary stiffening	800
• primary girders and web frames	1000
Main/strength deck structures:	
• secondary stiffening	1000
• primary girders and web frames	1250
• hatch covers	1250
Superstructures/deckhouses stiffeners:	
(a) Generally: • secondary	600
• primary	750
(b) Coachroof: • secondary	800
• primary	1000
(c) House top: • secondary	600
• primary	600
Lower/inner decks and house top subject to personnel loading:	
• secondary members	800
• primary members	1000
Deep tank stiffeners:	
• secondary members	1000
• primary members	1250
Watertight bulkhead stiffeners:	
• secondary members	600
• primary members	750
Multi-hull cross-deck stiffeners:	
• secondary members	800
• primary members	1000
Vehicle deck stiffeners:	
• secondary members	1000
• primary members	1250
Helicopter/flight decks stiffeners:	
• secondary members	1000
• primary members	1250
NOTE Where significant curvature exists over the span of the stiffener or breadth of the panel, the allowable deflections will be specially considered.	

Section 3 Stress control

3.1 General

3.1.1 The nominal limiting stress requirements for plating and primary and secondary stiffening members subject to local loading conditions are given in terms of limiting stress coefficients, *see* Table 7.3.1. The coefficients are expressed as a proportion of the yield stress of the material.

3.1.2 The limiting stress coefficients for structural elements subject to global loading conditions are given in Table 7.3.2.

3.1.3 In the determination of the magnitude of the equivalent stress, σ_{eq}, it is assumed that the stresses are combined using the following formula:

$$\sigma_{eq} = \sqrt{\sigma_x{}^2 + \sigma_y{}^2 - \sigma_x\,\sigma_y + 3\tau^2}$$

where

σ_x = direct stress in the x direction

σ_y = direct stress in the y direction

τ = shear stress in the xy plane

Table 7.3.1 Limiting stress coefficients for local loading (*see continuation*)

Item		Limiting stress coefficient		
		Bending f_σ	Shear f_τ	Equivalent f_e
Shell envelope:				
(a) Bottom shell plating:	• slamming zone	0,85	–	–
	• elsewhere	0,75	–	–
(b) Side shell plating:	• slamming zone	0,85	–	–
	• elsewhere	0,75	–	–
(c) Keel		0,75	–	–
Bottom structure:				
(a) Secondary stiffening:	• slamming zone	0,75	0,75	–
	• elsewhere	0,65	0,65	–
(b) Primary girders and web frames		0,65	0,65	0,75
(c) Engine girders		0,55	0,55	0,75
Side structure:				
(a) Secondary stiffening:	• slamming zone	0,75	0,75	–
	• elsewhere	0,65	0,65	–
(b) Primary girders and web frames		0,65	0,65	0,75
Bow doors:				
(a) Plating		0,65	–	–
(b) Secondary stiffening		0,51	0,433	–
(c) Primary stiffening		0,51	0,34	0,64
Main/strength deck plating and stiffeners:				
(a) Plating		0,75	–	–
(b) Secondary stiffening		0,65	0,65	–
(c) Primary girders and web frame		0,65	0,65	0,75
(d) Hatch covers		0,55	0,55	0,64
Superstructures/deckhouses:				
(a) Deckhouse front, 1st tier:	• plating	0,65	–	–
	• stiffening	0,60	0,60	–
(b) Deckhouse front upper tiers:	• plating	0,75	–	–
	• stiffening	0,65	0,65	–
(c) Deckhouse aft and sides:	• plating	0,75	–	–
	• stiffening	0,75	0,75	–
(d) Coachroof:	• plating	0,65	–	–
	• stiffening	0,65	0,65	–
(e) House top:	• plating	0,75	–	–
	• stiffening	0,75	0,75	–
(f) Lower/inner decks and house top subject to personnel loading:				
	• plating	0,75	–	–
	• stiffening	0,60	0,60	–

Table 7.3.1 Limiting stress coefficients for local loading (*conclusion*)

Item		Limiting stress coefficient		
		Bending f_σ	Shear f_τ	Equivalent f_e
Bulkheads:				
(a) Watertight bulkhead:	• plating	1,0	—	—
	• secondary stiffening	0,95	0,95	—
	• primary stiffening	0,90	0,90	1,0
(b) Watertight bulkhead doors		0,825	0,825	—
(c) Structure supporting watertight doors		0,80	0,80	
(d) Minor bulkheads:	• plating	0,65	—	—
	• secondary stiffening	0,65	0,65	—
	• primary stiffening	0,65	0,65	0,75
(e) Deep tank bulkheads:	• plating	0,65	—	—
	• secondary stiffening	0,65	0,65	—
	• primary stiffening	0,75	0,75	—
Multi-hull cross-deck structure:				
(a) Plating:	• slamming zone	0,85	—	—
	• elsewhere	0,75	—	—
(b) Secondary stiffening:	• slamming zone	0,75	0,75	—
	• elsewhere	0,65	0,65	—
(c) Primary stiffening		0,65	0,65	0,75
Vehicle deck:				
(a) Plating		0,6	—	—
(b) Secondary stiffening		0,425	0,425	—
(c) Primary stiffening		0,525	0,525	0,75
Helicopter/flight decks:				
(a) Normal usage:	• plating	0,65	—	—
	• secondary stiffening	0,75	0,75	—
	• primary stiffening	0,625	0,625	0,6
(b) Emergency landing:	• plating	0,75	—	—
	• secondary stiffening	1,0	1,00	—
	• primary stiffening	0,825	0,825	0,9
(c) Crane pedestal/foundation structural elements		0,7	0,70	0,75

Table 7.3.2 Limiting stress coefficients for global loading

Operational mode of craft	Limiting stress coefficient					
	Hull girder			Cross-deck		
	Bending $f_{\sigma gH}$	Shear $f_{\tau gH}$	Equivalent $f_{\sigma eg}$	Bending $f_{\sigma gV}$	Shear $f_{\tau gV}$	Equivalent $f_{\sigma eg}$
$\Gamma \geq 3{,}0$ or $\Delta \leq 0{,}04(L_R\,B)^{1,5}$	0,80 η_{HTS}	0,80 η_{HTS}	0,825 η_{HTS}	0,80 η_{HTS}	0,80 η_{HTS}	0,825 η_{HTS}
$\Gamma < 3{,}0$ and $\Delta > 0{,}04(L_R\,B)^{1,5}$	0,72 η_{HTS}	0,72 η_{HTS}	0,75 η_{HTS}	0,72 η_{HTS}	0,72 η_{HTS}	0,75 η_{HTS}

NOTES
$f_{\sigma gH}$ = limiting hull bending stress coefficient
$f_{\tau gH}$ = limiting hull shear stress coefficient
$f_{\sigma gV}$ = limiting cross-deck bending stress coefficient
$f_{\tau gV}$ = limiting cross-deck shear stress coefficient
$f_{\sigma eg}$ = limiting equivalent stress coefficient
Δ is the displacement as defined in Pt 5, Ch 2,2
Γ is the Taylor Quotient as defined in Pt 5, Ch 2,2.1.16
L_R and B are as defined in Pt 3, Ch 1,6.2
η_{HTS} is as defined in Ch 2,2.4.3

■ *Section 4* Buckling control

4.1 General

4.1.1 This Section contains the requirements for buckling control of plate panels subject to in-plane compressive and/or shear stresses and buckling control of primary and secondary stiffening members subject to axial compressive and shear stresses.

4.1.2 The requirements for buckling control of plate panels are contained in 4.3 to 4.6. The requirements for secondary stiffening members are contained in 4.7 to 4.8. The requirements for primary members are contained in 4.9 and 4.10.

4.1.3 In general all areas of the structure are to meet the buckling strength requirements for the design stresses. The design stresses are to be taken as follows:

(a) Global hull girder bending and shear stresses given in Chapter 6, but not including stresses σ_l and σ_t as defined in Table 6.2.1 in Chapter 6.
(b) Stresses from local compressive loads.

4.1.4 The buckling requirements are to be met using the net scantlings, hence any additional thickness for corrosion margin or Owners extra is not included in scantlings used to assess the buckling performance.

4.2 Symbols

4.2.1 The symbols used in this Section are defined below and in the appropriate sub-Section:

t_p = thickness of plating, in mm
A_R = panel aspect ratio
$= \dfrac{a}{b}$
a = panel length, i.e. parallel to direction of compressive stress being considered, in mm
b = panel breadth, i.e. perpendicular to direction of compressive stress being considered, in mm
S_p = span of primary members, in metres
σ_o = specified minimum yield strength of the material, in N/mm^2
σ_e = elastic compressive buckling stress, in N/mm^2
σ_c = critical compressive buckling stress, including the effects of plasticity where appropriate, in N/mm^2
τ_o = specified minimum yield shear stress of the material, in N/mm^2
$= \dfrac{\sigma_o}{\sqrt{3}}$ N/mm^2
E = modulus of elasticity of material in N/mm^2
τ_e = elastic shear buckling stress, in N/mm^2
τ_c = critical shear buckling stress, in N/mm^2
b_{eb} = lesser of $1{,}9 t_p \sqrt{\dfrac{E}{\sigma_o}}$ or $0{,}8b$ mm
A_{te} = cross-sectional area of secondary stiffener, in cm^2, including an effective breadth of attached plating, b_{eb}
s = length of shorter edge of plate panel, in mm (typically the spacing of secondary stiffeners)
l = length of longer edge of plate panel, in metres.
S = spacing of primary member, in metres (measured in direction of compression)

4.3 Plate panel buckling requirements

4.3.1 This Section gives methods for evaluating the buckling strength of plate panels subjected to the following load fields:

(a) uni-axial compressive loads;
(b) shear loads;
(c) bi-axial compressive loads;
(d) uni-axial compressive loads and shear loads;
(e) bi-axial compressive loads and shear loads.

4.3.2 The plate panel buckling requirements will be satisfied if the buckling interaction equations given in Table 7.4.2 for the above load fields are complied with.

4.3.3 The critical compressive buckling stresses and critical shear buckling stresses required for Table 7.4.2 are to be derived in accordance with 4.4.

4.3.4 The buckling factors of safety λ_σ and λ_τ required by Table 7.4.2 are given in Table 7.4.4 for the structural member concerned.

4.3.5 For all structural members which contribute to the hull girder strength, the plate panel buckling requirements for uni-axial compressive loads, Table 7.4.2(a), and shear loads, Table 7.4.2(b) are to be complied with.

4.3.6 In addition to 4.3.5, structural members which are subjected to local compressive loads and/or shear loads are to be verified using the plate panel buckling requirements in Table 7.4.2(c) to (e).

4.3.7 However, where some members of the structure have been designed such that elastic buckling of the plate panel between the stiffeners is allowable, then the requirements of 4.5 must be applied to the buckling analysis of the stiffeners supporting the plating. In addition, panels which do not satisfy the panel buckling requirements must be indicated on the appropriate drawing and the effect of these panels not being effective in transmitting compressive loads taken into account for the hull girder strength calculation.

4.3.8 In general the plate panel buckling requirements for more complex load fields, *see* 4.3.1(c), (d) and (e), are to be complied with. Where this is not possible, due to elastic buckling of the panel, then the critical buckling stress, σ_c, may be based on the ultimate collapse strength of the plating, σ_u from 4.5.4, instead of the elastic buckling stress, σ_e, derived in 4.3.5. In addition, the requirements of 4.5 are to be met for the supporting secondary stiffeners and primary members.

4.4 Derivation of the buckling stress for plate panels

4.4.1 The critical compressive buckling stress, σ_c, for a plate panel subjected to uni-axial in-plane compressive loads is to be derived in accordance with Table 7.4.1(a).

4.4.2 The critical shear buckling stress, τ_c, for a plate panel subjected to pure in-plane shear load is to be derived in accordance with Table 7.4.1(b).

4.4.3 For welded plate panels with plating thicknesses below 8 mm the critical compressive buckling stress is to be reduced to account for the presence of residual welding stresses. The critical buckling stress is to be taken as the minimum of:

$\sigma_{cr} = \sigma_e - \sigma_r$

or σ_c as derived using 4.4.1

where

σ_r = reduction in compressive buckling stress due to residual welding stresses

$$= \frac{2\beta_{RS}\,\sigma_o}{b/t_p}$$

β_{RS} = residual stress coefficient dependent on type of weld (average value of β_{RS} to be taken as 3)

b, t_p and σ_o are defined in 4.2.1.

4.4.4 In general the effect of lateral loading on plate panels (for example hydrostatic pressure on bottom shell plating) may be neglected and the critical buckling stresses calculated considering the in-plane stresses only.

4.4.5 Unless indicated otherwise, the effect of initial deflection on the buckling strength of plate panels may be ignored.

4.5 Additional requirements for plate panels which buckle elastically

4.5.1 Elastic buckling of plate panels between stiffeners occurs when both the following conditions are satisfied:

(a) The design compressive stress, σ_d, is greater than the elastic buckling stress of the plating, σ_e,

$\sigma_d > \sigma_e$

(b) The elastic buckling stress is less than half the yield stress

$$\sigma_e \le \frac{\sigma_o}{2}$$

4.5.2 Elastic buckling of local plating between stiffeners, including girders or floors, etc., may be allowed if all of the following conditions are satisfied:

(a) The critical buckling stress of the stiffeners in all buckling modes is greater than the axial stress in the stiffeners after redistribution of the load from the elastically buckled plating into the stiffeners, hence

$$\frac{\sigma_{de}}{\sigma_{c\,(i)}} \le \frac{1}{\lambda_\sigma}$$

(b) Maximum predicted loadings are used in the calculations.

(c) Functional requirements will allow a degree of plating deformation.

where

σ_{de} is the stiffener axial stress given in 4.5.5

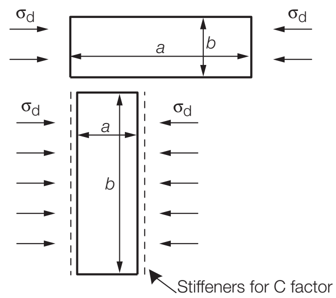
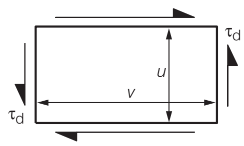
$\sigma_{c\,(i)}$ is given by Table 7.4.3

where

i = a, t, w or f depending on the mode of buckling.

λ_σ is the buckling factor of safety = 1,25.

Table 7.4.1 Buckling stress of plate panels

Mode	Elastic buckling stress, N/mm^2 *see* Note 1	
(a) Uni-axial compression: (i) Long narrow panels, loaded on the narrow edge (ii) Short broad panels, loaded on the broad edge	$A_R \geq 1$ $\sigma_e = 3{,}62\varphi E \left(\frac{t_p}{b}\right)^2$ $A_R < 1$ $\sigma_e = 0{,}9C\,\varphi \left(\frac{b}{a} + \frac{a}{b}\right)^2 E \left(\frac{t_p}{b}\right)^2$	
(b) Pure shear:	$\tau_e = 3{,}62\left(1{,}335 + \left(\frac{u}{v}\right)^2\right) E \left(\frac{t_p}{u}\right)^2$ *See* Note 2	

NOTES

1. The critical buckling stresses, in N/mm^2, are to be derived from the elastic buckling stresses as follows:

$$\sigma_c = \sigma_e \text{ when } \sigma_e < \frac{\sigma_o}{2}$$

$$= \sigma_o\left(1 - \frac{\sigma_o}{4\sigma_e}\right) \text{ when } \sigma_e \geq \frac{\sigma_o}{2}$$

σ_c is defined in 4.2.1
σ_o is defined in 4.2.1

$$\tau_c = \tau_e \text{ when } \tau_e < \frac{\tau_o}{2}$$

$$= \tau_o\left(1 - \frac{\tau_o}{4\tau_e}\right) \text{ when } \tau_e \geq \frac{\tau_o}{2}$$

τ_c is defined in 4.2.1
τ_o is defined in 4.2.1

2. *u* is to be the minimum dimension

Symbols and definitions

A_R = panel aspect ratio, *see* 4.2.1
σ_e = elastic compressive buckling stress, in N/mm^2
τ_e = elastic shear buckling stress, in N/mm^2
a and *b* are the panel dimensions in mm, *see* figures above
t_p = thickness of plating, in mm
φ = stress distribution factor for linearly varying compressive stress across plate width
= $0{,}47\mu^2 - 1{,}4\mu + 1{,}93$ for $\mu \geq 0$
= 1 for constant stress
μ = $\frac{\sigma_{d1}}{\sigma_{d2}}$ where σ_{d1} and σ_{d2} are the smaller and larger average compressive stresses respectively

E = Young's Modulus of elasticity of material, in N/mm^2
C = stiffener influence factor for panels with stiffeners perpendicular to compressive stress
= 1,3 when plating stiffened by floors or deep girders
= 1,21 when stiffeners are built up profiles or rolled angles
= 1,10 when stiffeners are bulb flats
= 1,05 when stiffeners are flat bars
σ_d and τ_d are the design compressive and design shear stresses in the direction illustrated in the figures. With linearly varying stress across the plate panel, σ_d is to be taken as σ_{d2}

4.5.3 The effective breadth of attached plating for stiffeners, girder or beams that is to be used for the determination of the critical buckling stress of the stiffeners attached to plating which buckles elastically is to be taken as follows:

$$b_{eu} = \frac{b\sigma_u}{\sigma_o} \text{ mm}$$

where

σ_u = ultimate buckling strength of plating as given in 4.5.4
b_{eu} = effective panel breadth perpendicular to direction of compressive stress being considered
b is given in 4.2.1.

4.5.4 The ultimate buckling strength of plating, σ_u, which buckles elastically, may be determined as follows:

(a) shortest edge loaded, i.e. $A_R \geq 1$:

$$\sigma_u = \sigma_o\left(\frac{1{,}9}{\Omega} - \frac{0{,}8}{\Omega^2}\right) \text{ N/mm}^2$$

(b) longest edge loaded, i.e. $A_R < 1$:

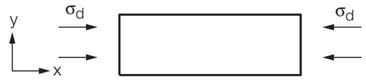
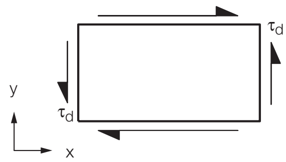
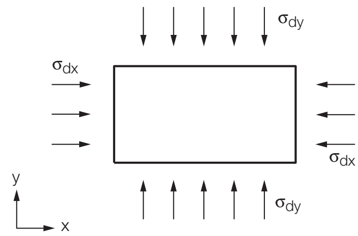
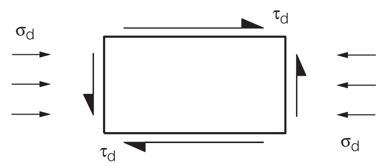
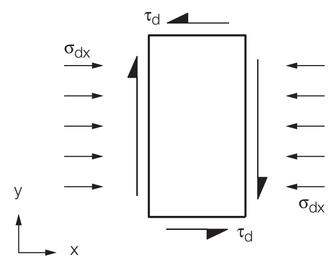
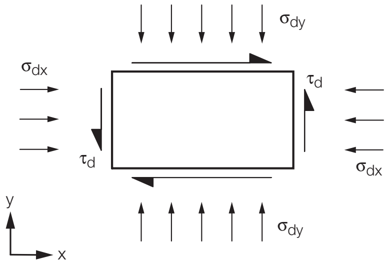
$$\sigma_u = \frac{1{,}77\sigma_o A_R^{0{,}78}}{\Omega} \text{ N/mm}^2$$

where

$$\Omega = \frac{s}{t_p}\sqrt{\frac{\sigma_o}{E}}$$

A_R and *s* are defined in 4.2.1.
t_p, *E* and σ_o are defined in 4.2.1.

Table 7.4.2 Plate panel buckling requirements

	Stress field	Buckling interaction formula	
(a)	uni-axial compressive loads	$\frac{\sigma_d}{\sigma_c} \leq \frac{1}{\lambda_\sigma}$	
(b)	shear loads	$\frac{\tau_d}{\tau_c} \leq \frac{1}{\lambda_\tau}$	
(c)	bi-axial compressive loads	for A_R = 1,0 $\frac{\sigma_{dx}}{\sigma_{cx}} + \frac{\sigma_{dy}}{\sigma_{cy}} \leq 1{,}0$ for other aspect ratios, i.e. $A_R \neq 1{,}0$ $\frac{\sigma_{dx}}{\sigma_{cx}} + \frac{\sigma_{dy}}{\sigma_{cy}} \leq G$ where *G* is taken from Fig. 7.4.3	
(d)	uni-axial compressive loads plus shear load	for $A_R > 1$ $\left(\frac{\sigma_d}{\sigma_c}\right) + \left(\frac{\tau_d}{\tau_c}\right)^2 \leq 1$ for $A_R \leq 1$ $\left(\frac{1 + 0{,}6A_R}{1{,}6}\right)\left(\frac{\sigma_d}{\sigma_c}\right) + \left(\frac{\tau_d}{\tau_c}\right)^2 \leq 1$	 
(e)	bi-axial compressive loads plus shear loads	$\frac{0{,}625\left(1 + \frac{0{,}6}{A_R}\right)\left(\frac{\sigma_{dy}}{\sigma_{cy}}\right)}{1 - 0.625\left(\frac{\sigma_{dx}}{\sigma_{cx}}\right)} + \frac{\left(\frac{\tau_d}{\tau_c}\right)^2}{1 - \left(\frac{\sigma_{dx}}{\sigma_{cx}}\right)} \leq 1$	

Symbols

σ_d = design compressive stress, *see* 4.1.3
σ_c = critical compressive buckling stress, in N/mm^2, for uniaxial compressive load acting independently, *see* 4.3.5
σ_{dx} = design compressive stress in x direction
σ_{dy} = design compressive stress in the y direction
σ_{cx} = critical compressive buckling stress in x direction, *see* 4.3.5
σ_{cy} = critical compressive buckling stress in y direction, *see* 4.3.5
λ_σ = buckling factor of safety for compressive stresses, *see* 4.3.4
λ_τ = buckling factor of safety for shear stresses, *see* 4.3.4
τ_d = design shear stress, in N/mm^2
τ_c = critical shear buckling stress, in N/mm^2, acting independently, *see* 4.3.5

Table 7.4.3 Buckling stress of secondary stiffeners (*see continuation*)

Mode	Elastic buckling stress, N/mm^2	Critical buckling stress, N/mm^2 *see* Note 1
(a) Overall buckling (perpendicular to plane of plating without rotation of cross-section)	$\sigma_{e(a)} = C_f\, 0{,}001\, E \dfrac{I_a}{A_{te}\, l_e^2}$	$\sigma_{c(a)}$
(b) Torsional buckling	$\sigma_{e(t)} = \dfrac{0{,}001 E\, I_w}{I_p\, l_e^2}\left(m^2 + \dfrac{K}{m^2}\right) + 0{,}385E\, \dfrac{I_t}{I_p}$	$\sigma_{c(t)}$
(c) Web buckling (excluding flat bar stiffeners)	$\sigma_{e(w)} = 3{,}8\, E \left(\dfrac{t_w}{d_w}\right)^2$	$\sigma_{c(w)}$
(d) Flange buckling	$\sigma_{e(f)} = 0{,}39\, E \left(\dfrac{t_f}{b_f}\right)^2$	$\sigma_{c(f)}$

Symbols

d_w = web depth, in mm, (excluding flange thickness for rolled sections), *see* Fig. 7.4.4
t_w = web thickness, in mm
b_f = flange width, in mm (including web thickness)
t_f = flange thickness, in mm. For bulb plates, the mean thickness of the bulb may be used, *see* Fig. 7.4.4
l_e = effective span length of stiffener, in metres
C_f = end constraint factor
= 1 where both ends are pinned
= 2 where one end is pinned and the other end is fixed
= 4 where both ends are fixed
E = Young's Modulus of elasticity of the material, in N/mm^2
I_a = moment of inertia, in cm^4, of longitudinal, including attached plating of effective width b_{eb}, *see* Note 2
t_p and σ_o are given in 4.2.1
A_{te} and b_{eb} are given in 4.2.1
I_t = St.Venant's moment of inertia, in cm^4, of longitudinal (without attached plating)

$$= \frac{d_w\, t_w^3}{3}\, 10^{-4} \quad \text{for flat bars}$$

$$= \frac{1}{3}\left[d_w\, t_w^3 + b_f\, t_f^3 \left(1 - \frac{0{,}63\, t_f}{b_f}\right)\right] 10^{-4} \quad \text{for built up profiles, rolled angles and bulb plates}$$

I_p = polar moment of inertia, in cm^4, of profile about connection of stiffener to plating

$$= \frac{d_w^3\, t_w}{3}\, 10^{-4} \quad \text{for flat bars}$$

$$= \left(\frac{d_w^3\, t_w}{3} + d_w^2\, b_f\, t_f\right) 10^{-4} \quad \text{for built up profiles, rolled angles and bulb plates}$$

I_w = sectional moment of inertia, in cm^6, of profile and connection of stiffener to plating

$$= \frac{d_w^3\, t_w^3}{36}\, 10^{-6} \quad \text{for flat bars}$$

$$= \frac{t_f\, b_f^3\, d_w^2}{12}\, 10^{-6} \quad \text{for 'Tee' profiles}$$

$$= \frac{b_f^3\, d_w^2}{12\,(b_f + d_w)^2}\,(t_f\,(b_f^2 + 2b_f\, d_w + 4d_w^2) + 3t_w\, b_f\, d_w)\, 10^{-6} \quad \text{for '}L\text{' profiles, rolled angles and bulb plates}$$

C = spring stiffness exerted by supporting plate panel

$$= \frac{k_p\, E\, t_p^3}{3b\left(1 + \dfrac{1{,}33 k_p\, d_w\, t_p^3}{b\, t_w^3}\right)}$$

k_p = 1 – η_p, and is not to be taken as less than zero. For built up profiles, rolled angles and bulb plates, k_p need not be taken less than 0,1

$$\eta_p = \frac{\sigma_d}{\sigma_{ep}}$$

σ_{ep} = elastic critical buckling stress, in N/mm^2, of the supporting plate derived from Table 7.4.1

Table 7.4.3 Buckling stress of secondary stiffeners (*conclusion*)

m is determined as follows; e.g. m = 2 for K = 25

K	0 to 4	4 to 36	36 to 144	144 to 400	400 to 900	900 to 1764	$(m-1)^2\,m^2$ to $m^2\,(m+1)^2$
m	1	2	3	4	5	6	m

$$K = \frac{1{,}03CS^4}{E\,I_w}\,10^4$$

σ_d is the design stress, in N/mm^2
all other symbols are as defined in 4.2.1.

NOTES
1. The critical buckling stresses are to be derived from the elastic buckling stresses as follows:

$$\sigma_c = \sigma_e \text{ when } \sigma_e < \frac{\sigma_o}{2}$$

$$= \sigma_o\left(1 - \frac{\sigma_o}{4\sigma_e}\right) \text{when } \sigma_e \geq \frac{\sigma_o}{2}$$

2. For stiffeners attached to plating which buckles elastically, *see* 4.5, the effective width of plating is to be taken as b_{eu}.

4.5.5 The axial stress in stiffeners attached to plating which is likely to buckle elastically is to be derived as follows:

$$\sigma_{de} = \sigma_d \frac{A_t}{A_{tb}}$$

where

σ_d is the axial stress in the stiffener when the plating can be considered fully effective

$$A_t = A_s + \frac{bt}{100} \text{ cm}^2$$

$$A_{tb} = A_s + \frac{b_{eu}\,t}{100} \text{ cm}^2$$

where

b and b_{eu} are given in 4.5.3
t is the plating thickness, in mm
A_s is the stiffener area in cm^2.

4.6 Shear buckling of stiffened panels

4.6.1 The shear buckling capability of longitudinally stiffened panels between primary members is to satisfy the following condition:

$$\frac{\tau_d}{\tau_c} \leq \frac{1}{\lambda_\tau}$$

where

τ_c is derived from 4.6.3
τ_d is the design shear stress
λ_τ is given in Table 7.4.4.

Table 7.4.4 Buckling factor of safety

Structural item	Buckling factor of safety (2) Compressive stresses, λ_σ	Buckling factor of safety (3) Shear stresses, λ_τ
Bottom shell plating	1,0	—
Inner bottom plating	1,0	—
Deck plating	1,0	—
Side shell plating	1,0	1,1
Longitudinal bulkhead plating	1,0	1,1
Double bottom girders	1,0	1,1
Longitudinal girders	1,0	1,1
Superstructures/deckhouses (partially longitudinally effective)	1,0	—
Longitudinal secondary stiffeners	1,1 (1)	—
Girder and floor web plating subject to local loads	1,1	1,2

NOTES
1. The buckling factor of safety for stiffeners attached to plating which is allowed to buckle in the elastic mode due to the applied loads is to be taken as 1,25, *see also* 4.5.
2. Buckling factor of safety to be applied to the compressive stress due to global longitudinal stresses.
3. Buckling factor of safety to be applied to the shear stress.

4.6.2 The elastic shear buckling stress of longitudinally stiffened panels between primary members may be taken as:

$$\tau_e = K_s E \left(\frac{t}{s}\right)^2 \quad \text{for } A_R \geq 1$$

where

$K_s = 4{,}5\left(\left(\frac{s}{1000l}\right)^2 + \frac{1}{N^2} + \left(\frac{N^2-1}{N^2}\right)\left(\frac{\omega}{1+\omega}\right)^r\right)$

N = number of subpanels

$= \frac{1000S_p}{s}$

$\omega = \frac{10I_{se}}{l\,t^3}$

I_{se} = moment of inertia of a section, in cm^4, consisting of the longitudinal stiffener and a plate flange of effective width $s/2$

$r = 1 - 0{,}75\left(\frac{s}{1000l}\right)$

s, l, E and S_p are as defined in 4.2.1, *see also* Fig. 7.4.1.

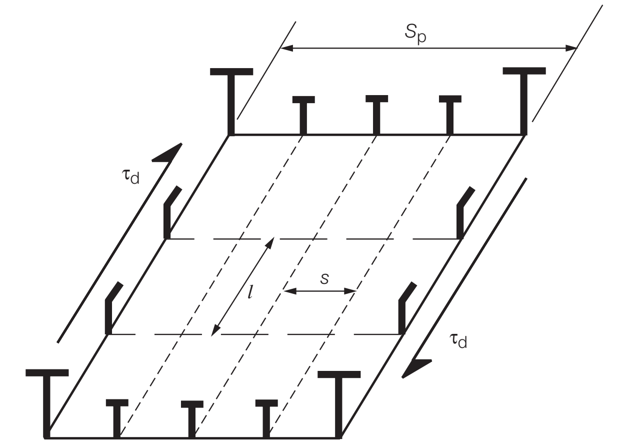


Fig. 7.4.1
Shear buckling of stiffened panels

4.6.3 The critical shear buckling stress, τ_c, may be determined from τ_e, *see* Note 2 in Table 7.4.1.

4.7 Secondary stiffening in direction of compression

4.7.1 The buckling performance of stiffeners will be considered satisfactory if the following conditions are satisfied:

$$\frac{\sigma_d}{\sigma_{c(a)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(t)}} \leq \frac{1}{\lambda_\sigma}$$

$$\frac{\sigma_d}{\sigma_{c(w)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(f)}} \leq \frac{1}{\lambda_\sigma}$$

where

$\sigma_{c(a)}$, $\sigma_{c(t)}$, $\sigma_{c(w)}$ and $\sigma_{c(f)}$ are the critical buckling stress of the stiffener for each mode of failure, *see* 4.7.2

σ_d is the design compressive stress, *see also* 4.5 and 4.1.3

λ_σ is the buckling factor of safety given in Table 7.4.4. The value of λ_σ to be chosen depends on the buckling assessment of the attached plating, *see* Note 1, Table 7.4.4.

4.7.2 The critical buckling stresses for the overall, torsional, web and flange buckling modes of longitudinals and secondary stiffening members under axial compressive loads are to be determined in accordance with Table 7.4.3.

4.7.3 To prevent torsional buckling of secondary stiffeners from occurring before buckling of the plating, the critical torsional buckling stress, $\sigma_{c(t)}$, is to be greater than the critical buckling stress of the attached plating as detailed in 4.4.1.

4.7.4 The critical buckling stresses of the stiffener web, $\sigma_{c(w)}$, and flange, $\sigma_{c(f)}$, are to be greater than the critical torsional buckling stress, hence:

$\sigma_{c(w)} > \sigma_{c(t)}$

$\sigma_{c(f)} > \sigma_{c(t)}$

4.7.5 To ensure that overall buckling of the stiffened panel cannot occur before local buckling of the secondary stiffener, the critical overall buckling stress $\sigma_{c(a)}$, is to be greater than the critical torsional buckling stress, hence:

$\sigma_{c(a)} > \sigma_{c(t)}$

4.8 Secondary stiffening perpendicular to direction of compression

4.8.1 Where a stiffened panel of plating is subjected to a compressive load perpendicular to the direction of the stiffeners, *see* Fig. 7.4.2, e.g. a transversely stiffened panel subject to longitudinal compressive load, the requirements of this Section are to be applied.

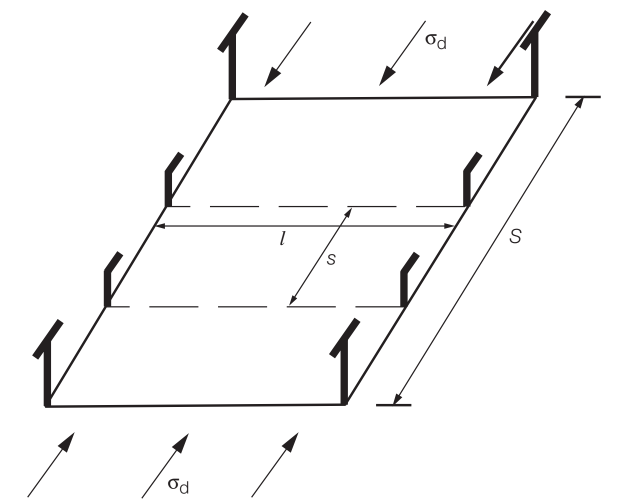


Fig. 7.4.2
Secondary stiffening perpendicular to direction of compression

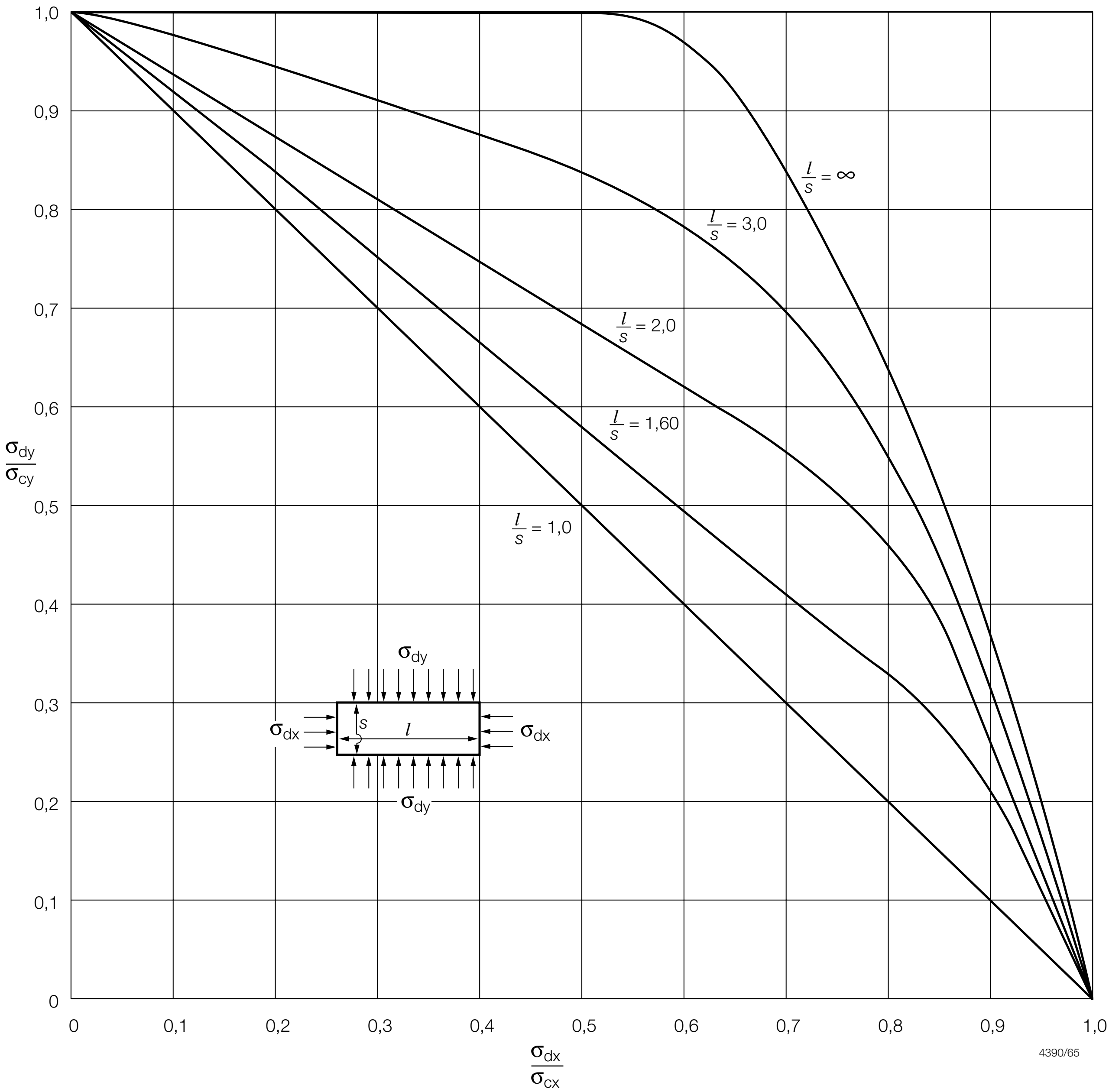


Fig. 7.4.3
Interaction limiting stress curves of G for plate panels subject to bi-axial compression, *see* Table 7.4.2(c)

4.8.2 The minimum area moment of inertia of each stiffener including attached plating of width, s, to ensure that overall panel buckling does not precede plate buckling is to be taken as:

$$I_s = \frac{D\, s\, (4N_L^2 - 1)((N_L^2 - 1)^2 - 2\,(N_L^2 + 1)\,\kappa + \kappa^2)}{2\,(5N_L^2 + 1 - \kappa)\,\Pi^4\, E} \text{ mm}^4$$

where

$$D = \frac{E\, t_p^3}{12\,(1 - \upsilon^2)}$$

$\kappa = A_R^2\, \Pi^2$

A_R = plate panel aspect ratio

$$= \frac{s}{1000l}$$

$$\Pi = \frac{S}{l}$$

N_L = number of plate panels

$N_L - 1$ = number of stiffeners

υ = 0,3

s, l and S are defined in 4.2.1 and shown in Fig. 7.4.2.

t_p and E are defined in 4.2.1.

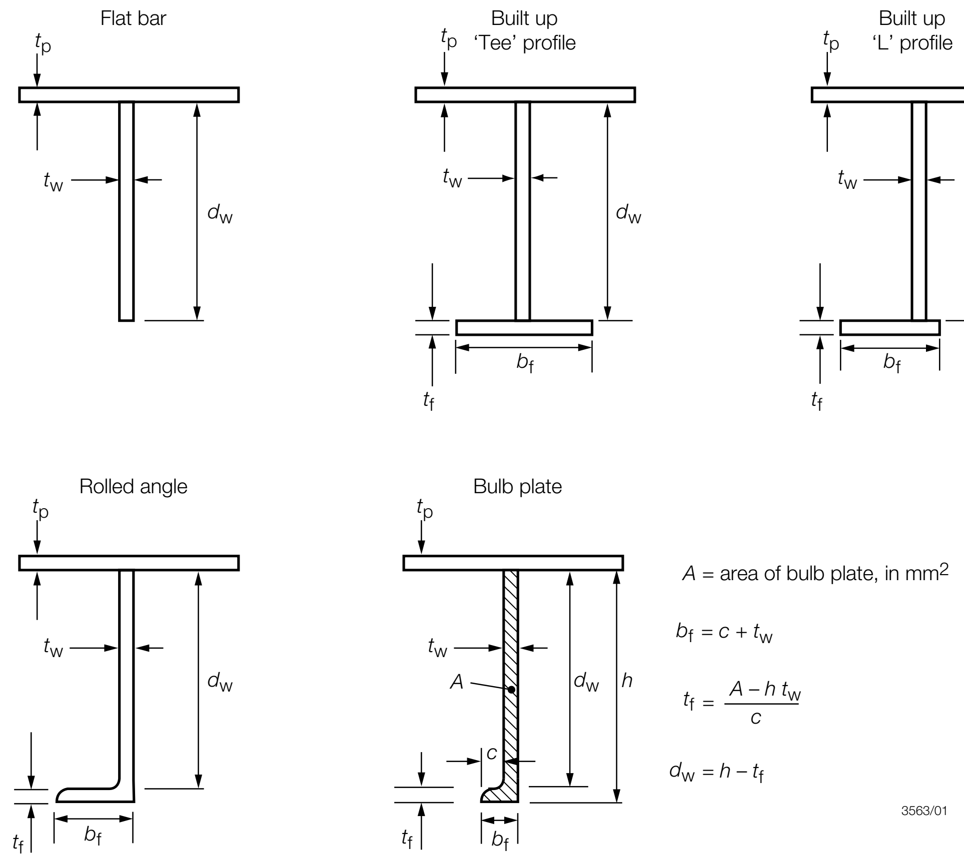


Fig. 7.4.4 Dimensions of longitudinals

4.9 Buckling of primary members

4.9.1 Where primary girders are subject to axial compressive loading, the buckling requirements for lateral, torsional, web and flange buckling modes detailed in 4.7 are to be satisfied.

4.9.2 To prevent global buckling from occurring before local panel buckling, transverse primary girders supporting axially loaded longitudinal stiffeners are to have a sectional moment of inertia, including attached plating, of not less than the following:

$$I_g = \frac{0{,}35 S_p^4 I_s}{l^3 s} \times 10^3 \text{ cm}^4$$

S_p and s are as defined in 4.2.1, *see also* Fig. 7.4.1

I_g = sectional moment of inertia including attached plating

I_s = moment of inertia of secondary stiffeners, in cm^4, required to satisfy the overall elastic column buckling mode requirement specified in Table 7.4.3

$$= \frac{\sigma_{ep} A_{te} l_e^2}{0{,}001E}$$

where

$$\sigma_{ep} = 1{,}2\sigma_d \text{ N/mm}^2 \text{ for } \sigma_{e(a)} < \frac{\sigma_o}{2}$$

$$= \frac{\sigma_o^2}{4(\sigma_o - 1{,}2\sigma_d)} \text{ for } \sigma_{e(a)} \geq \frac{\sigma_o}{2}$$

σ_d is design stress, in N/mm^2
σ_o and A_{te} are as defined in 4.2.1
$\sigma_{e(a)}$ is the elastic column buckling stress, *see* 4.7.2
E is defined in 4.2.1.
l_e is defined in Table 7.4.3.

4.10 Shear buckling of girder webs

4.10.1 Local panels in girder webs subject to in-plane shear loads are to satisfy the shear buckling requirements in Table 7.4.2, item (b).

4.10.2 The critical shear buckling stress, τ_c, is to be determined using the following formula for τ_e and Note 1 in Table 7.4.1.

$$\tau_e = 3{,}62\left(1{,}335 + \left(\frac{d_w}{1000\, l_p}\right)^2\right) E \left(\frac{t_w}{d_w}\right)^2 \text{ N/mm}^2$$

where

d_w = web height, in mm
t_w = web thickness, in mm
l_p = unsupported length of web, in metres
E is defined in 4.2.1.

4.11 Pillars and pillar bulkheads

4.11.1 Pillars and pillar bulkheads are to comply with the requirements of Ch 3,10.

Section 5
Vibration control

5.1 General

5.1.1 Natural frequencies are to be investigated for local unstiffened and stiffened panels expected to be exposed to excessive structural vibrations being induced from machinery, propulsion unit or other potential excitation sources.

5.1.2 Where the structural configurations are such that basic structural elements may be modelled individually the natural frequencies may be derived in accordance with 5.3, 5.4 and 5.5, as appropriate. Under other circumstances finite element analysis is to be employed to evaluate the vibration characteristics of the structure considered.

5.2 Frequency band

5.2.1 The natural frequency of panels is generally not to lie within a band of ±20 per cent of a significant excitation frequency.

5.3 Natural frequency of plate

5.3.1 The natural frequency of a clamped plate in air is given by the following:

$$f_{air} = 5{,}544 \frac{t_p}{ab} \sqrt{\left(\frac{a}{b}\right)^2 + \left(\frac{b}{a}\right)^2 + 0{,}6045} \text{ Hz}$$

where

a = panel length, in metres
b = panel breadth, in metres
t_p = panel thickness, in mm

5.4 Natural frequency of plate stiffener

5.4.1 The natural frequency of a plate stiffener in air is given by the following:

$$f_{air,i} = \frac{K_i}{2\pi L_b^2} \sqrt{\frac{E\,I}{m\left(1 + \dfrac{\pi^2 E\,I}{L_b^2\,GA}\right)}} \text{ Hz}$$

where

$E\,I$ = flexural rigidity of plate stiffener combination, in Nm^2
GA = shear rigidity of plate stiffener combination, in N
L_b = beam length, in metres
m = mass per unit length of the stiffener and associated plating, in kg/m
K_i = constant where i refers to the mode of vibration as given in Table 7.5.1.

Table 7.5.1 Vibration mode constant K_i

Mode	1	2	3	4	5
K_i	22,40	61,70	121,0	200,0	299,0

5.5 Effect of submergence

5.5.1 To obtain the frequency, f_{water}, of a plate with one side exposed to air and the other side exposed to a liquid, the frequency calculated in air, f_{air}, may be modified by the following formula:

$$f_{water} = \psi f_{air}$$

where

$$\psi = \sqrt{\frac{\kappa_p}{\kappa_p + \dfrac{\rho_l}{\rho_p}}}$$

ρ_l = density of the liquid, in kg/m^3
ρ_p = density of the plate, in kg/m^3

$$\kappa_p = \frac{\pi\, t_p}{1000 a\, b} \sqrt{a^2 + b^2}$$

where
a, b and t_p are as defined in 5.3.1.

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HULL CONSTRUCTION IN ALUMINIUM

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PART 7

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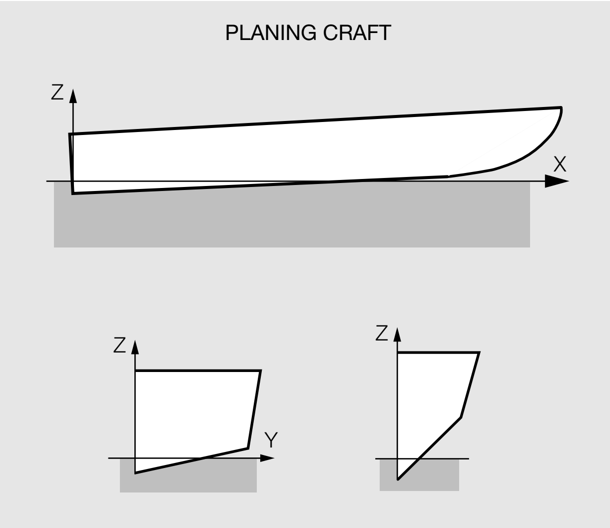
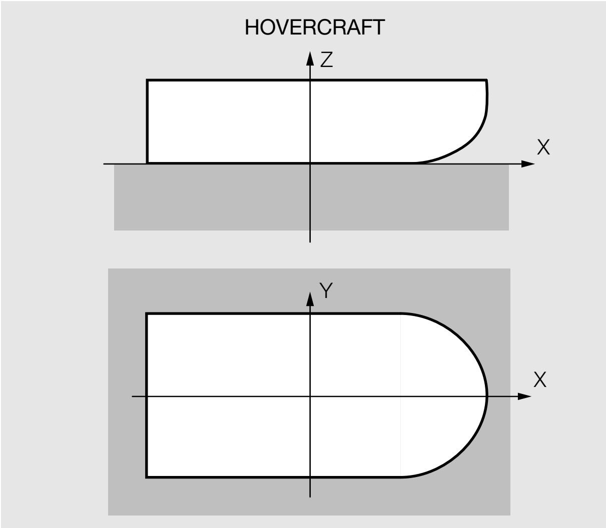
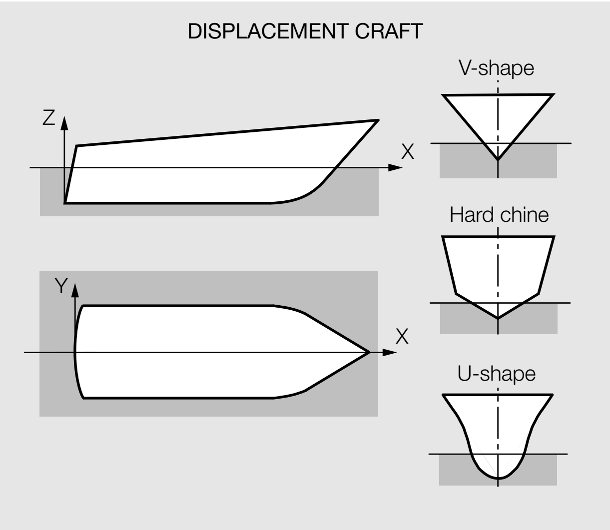
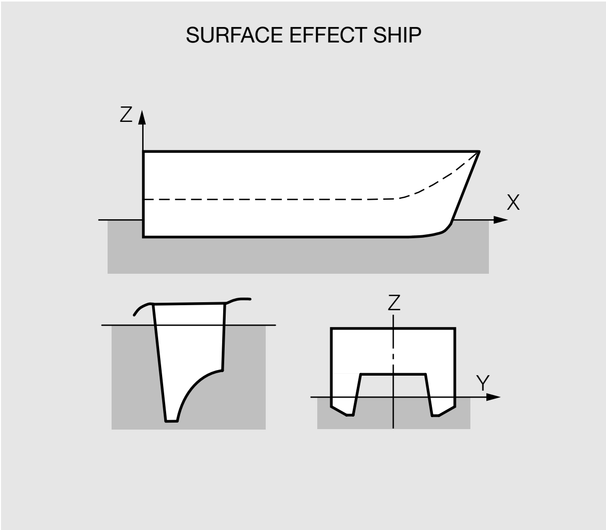
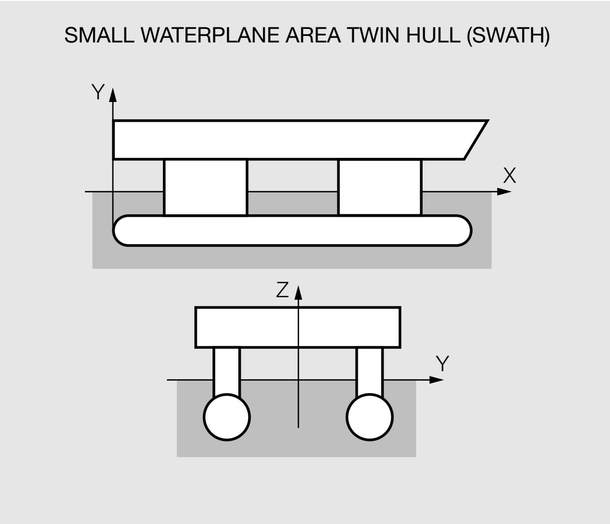
DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

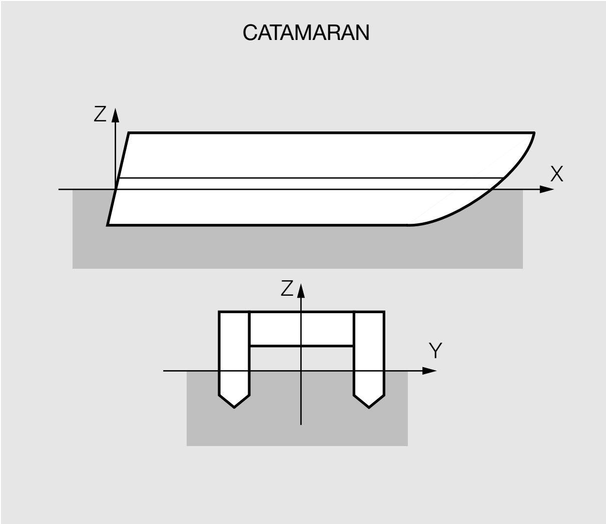




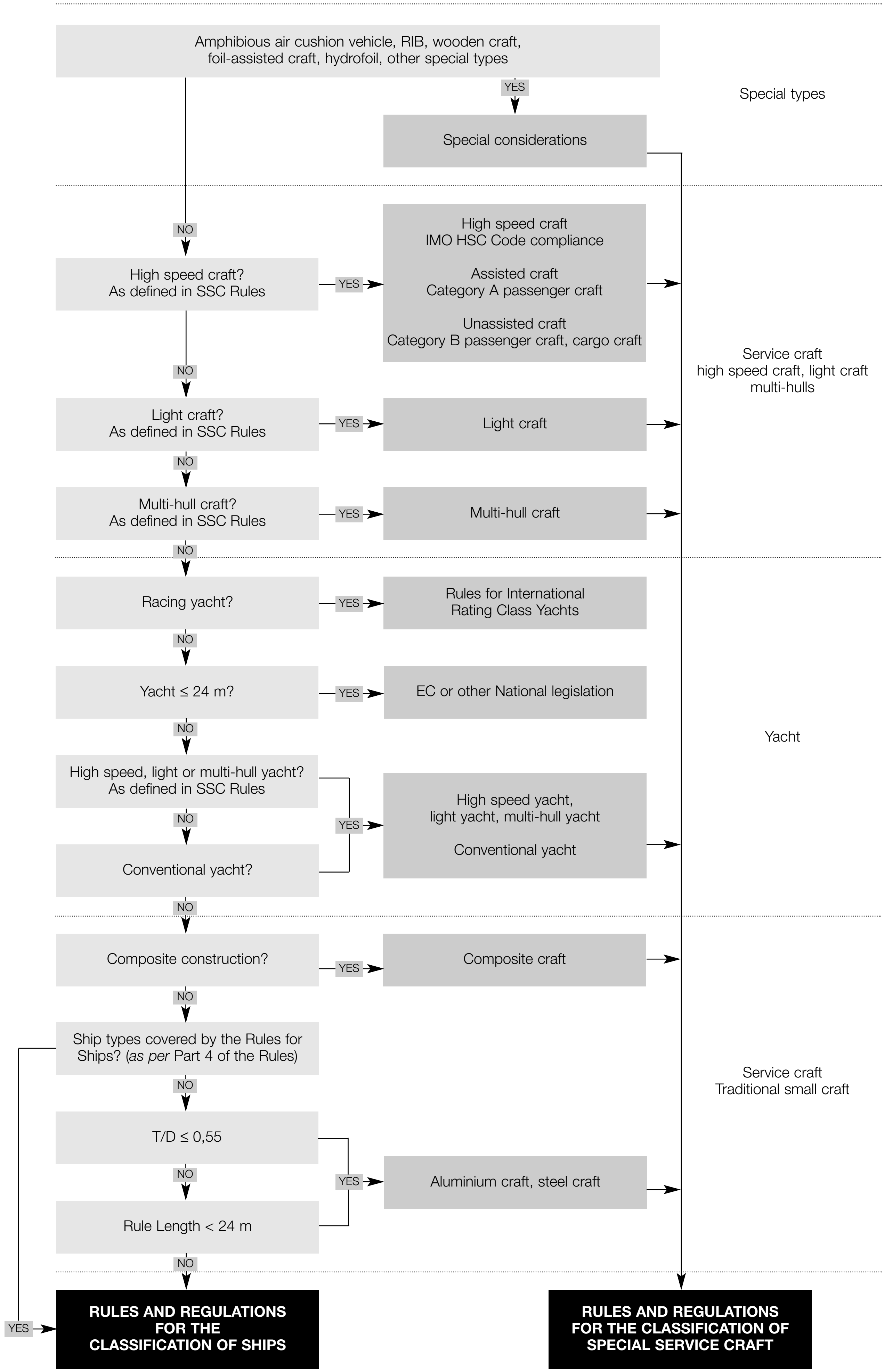








DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



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Part 7

Section

■ *Section 1* Application

1.1 General

1.1.1 The Rules apply to mono and multi-hull craft of normal form, proportions and speed. Although the Rules are, in general, for aluminium craft of all welded construction, other materials for use in hull construction will be specially considered on the basis of the Rules.

1.2 Interpretation

1.2.1 The interpretation of the Rules is the sole responsibility and at the sole discretion of Lloyd's Register (hereinafter referred to as 'LR'). Where there is any doubt, regarding the interpretation of the Rules it is the Builder's and/or designer's responsibility to obtain clarification from LR prior to submission of plans and data for appraisal.

1.2.2 Where applicable, the Rules take into account unified requirements and interpretations established by the International Association of Classification Societies (IACS).

1.2.3 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside classification as defined in the Rules.

1.3 Equivalents

1.3.1 Alternative scantlings and arrangements may be accepted as equivalent to the Rule requirements. Details of such proposals are to be submitted for consideration in accordance with Pt 3, Ch 1,3.

1.4 Symbols and definitions

1.4.1 The symbols and definitions for use throughout this Part are as defined within the appropriate Chapters and Sections.

■ *Section 2* General requirements

2.1 General

2.1.1 Limitations with regard to the application of these Rules are indicated in the various Chapters for differing craft types.

2.2 Aesthetics

2.2.1 LR is not concerned with the general arrangement, layout and appearance of the craft; the responsibility for such matters remains with the Builders and/or designers to ensure that the agreed specification is complied with. LR is however concerned with the quality of workmanship, in this respect the acceptance criteria as required by the Rules are to be complied with.

2.3 Constructional configuration

2.3.1 The Rules provide for the basic structural configurations for both single and multi-deck mono and multi-hull craft with multi-deck or single deck hulls which include a double bottom, or a single bottom arrangement. The structural configuration may also include a single or multiple arrangement of cargo hatch openings and side tanks.

2.3.2 The Rules provide for longitudinal and transverse framing systems.

2.3.3 Novel or other types of framing systems will be considered on the basis of the Rules.

2.4 Plans to be submitted

2.4.1 Plans covering the following items are to be submitted:

- Midship sections showing longitudinal and transverse material.
- Profile and decks.
- Shell expansion.
- Oiltight and watertight bulkheads.
- Propeller brackets.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Hatch cover construction.
- Deckhouses and superstructures.
- Sternframe.
- Rudder, stock and tiller.
- Equipment.
- Loading Manuals, preliminary and final (where applicable).
- Scheme of corrosion control (where applicable).
- Ice strengthening.
- Welding schedule.
- Hull penetration plans.
- Support structure for masts, derrick posts or cranes.
- Bilge keels showing material grades, welded connections and detail design.

2.4.2 The following supporting documents are to be submitted:

- General arrangement.
- Capacity plan.
- Lines plan or equivalent.
- Dry-docking plan.
- Towing and mooring arrangements.
- Sail/rigging plan, indicating loadings (as applicable to sailing craft).

2.4.3 The following supporting calculations are to be submitted:

- Equipment Number.
- Hull girder still water and dynamic bending moments and shear forces as applicable.
- Midship section modulus.
- Structural items in the aft end, midship and fore end regions of the craft.
- Preliminary freeboard calculation.

2.5 Novel features

2.5.1 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of LR, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the *Register Book*.

2.6 Enhanced scantlings

2.6.1 Where the Owner decides to increase the scantling of the bottom shell, side shell and deck plating of a newbuilding, then the craft will be eligible to be assigned the description note **ES**, *see* Pt 1, Ch 2,3.12. For example, the descriptive note **ES+1** would indicate that an extra 1 mm of aluminium has been fitted to bottom shell, side shell and deck plating.

2.7 Direct calculations

2.7.1 Direct calculations may be specifically required by the Rules and may be required for craft having novel design features or in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of designers and make recommendations with regard to suitability of any required model tests.

2.7.2 Where direct calculations are proposed then the requirements of Pt 3, Ch 1,2 of the Rules are, in general, to be complied with.

2.8 Exceptions

2.8.1 Craft of unusual form, proportions or speed, intended for the carriage of special cargoes, or for special or restricted service, not covered specifically by the Rules, will receive individual consideration based on the general requirements of the Rules.

2.9 Advisory services

2.9.1 The Rules do not cover certain technical characteristics, such as stability except as mentioned in Pt 1, Ch 2,1.1.11, 1.1.13 and 1.1.14, trim, vibration (other than local stiffened flat panels, *see* Ch 7,5), docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of aluminium construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 This Chapter contains the general Rule requirements for the construction of aluminium craft using the metal inert gas (MIG) and tungsten inert gas (TIG) welding processes. Where alternative methods of construction are proposed, details are to be submitted for consideration by Lloyd's Register (hereinafter referred to as 'LR').

1.3 Symbols and definitions

1.3.1 The symbols and definitions used in this Chapter are defined in the appropriate Section.

1.4 Builder's facilities

1.4.1 The buildings used for production and storage are to be of suitable construction and equipped to provide the required environment, and also to comply with any local or National Authority requirements.

1.4.2 The Surveyor is to be allowed unrestricted access during working hours to such parts of the Builder's establishment as may be necessary to ensure that the requirements of the Rules are being complied with.

1.5 Works inspection

1.5.1 Prior to the commencement of construction, the facilities are to be inspected to the satisfaction of the attending Surveyor. This will include the minimum quality control arrangements outlined in 1.6.

1.5.2 The Surveyor is to be satisfied that the Builder has the organisation and capability to construct craft to the standards required by the Rules.

1.5.3 The Builder is to be advised of the result of the inspection and all deficiencies are to be rectified prior to the commencement of production.

1.5.4 Where structural components are to be assembled and welded by sub-contractors, the Surveyors are to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter can be achieved.

1.6 Quality control

1.6.1 For compliance with 1.5.2, LR's methods of survey and inspection for hull construction and machinery installation are to include procedures involving the shipyard management, organisation and quality systems.

1.6.2 The extent and complexity of the quality systems, will vary considerably depending on the size and type of craft and production output. LR will consider certification of the Builder in accordance with the requirements of one of the following systems:

(a) Quality Assurance System in accordance with an International or National Standard (i.e. ISO 9000 and BS ENISO 9001) with assessment and certification carried out by a nationally accredited body.

(b) LR's *Quality Assurance Scheme for the Construction of Special Service Craft*.

(c) LR's locally accepted Quality Control System – The Builder is required to implement a documented Quality Control System which controls the following activities:
  - (i) Receipt storage and issue of materials, equipment, etc.
  - (ii) Fabrication environment.
  - (iii) Weld procedures and welder performance.
  - (iv) Production fabrication.
  - (v) Inspection of production processes.
  - (vi) Installation of machinery and essential systems.
  - (vii) Fitting-out.
  - (viii) Tests and trials.
  - (ix) Drawings and document control.
  - (x) Records.

1.6.3 LR's involvement is only in that part of the system which controls the standards required to meet the classification requirements.

1.6.4 The 'documented' quality control system will in general require the Builder to have written procedures that describe clearly and unambiguously how each of the activities specified in 1.6.2(c) is carried out, when it is carried out and by whom. These procedures will form part of the system manual which is also to contain a statement of management policy, organisation chart and statements of responsibilities. The manual is to be controlled in respect to the formal issue and revision.

1.6.5 Further details of LR's requirements are available on request from the local LR office.

1.7 Building environment

1.7.1 The craft is to be suitably protected during the building period from adverse weather and climatic conditions.

1.8 Storage areas

1.8.1 All materials are to be stored safely and in accordance with the manufacturer's requirements. Storage arrangements are to be such as to prevent deterioration through contact with heat, sunlight, damp, cold and poor handling.

1.8.2 Aluminium is to be stored in dry places, clear of the ground. Contact with other metals and with materials such as cement and damp timber is to be avoided. Aluminium sheet and plate are to be stacked, in general, on end in racks to avoid distortion.

1.8.3 All storage spaces provided by the Builder for welding consumables are to be suitable for maintaining them in good condition and are to be in accordance with the manufacturer's recommendations.

1.8.4 All materials are to be fully identifiable in the storage areas, and identification is to be maintained during issue to production.

1.8.5 Material suspected of being non-conforming is to be segregated from acceptable materials.

1.9 Materials handling

1.9.1 The Builder is to maintain purchasing documents containing a clear description of the materials ordered for use in hull construction and the standards to which the material must conform, together with the identification and certification requirements.

1.9.2 The Builder is to be responsible for ensuring that all incoming plates, sections, castings, components, fabrications and consumables and other materials used in the hull construction are inspected or otherwise verified as conforming to purchase order requirements.

1.9.3 The Builder is to have procedures for the inspection, storage and maintenance of Owner supplied materials and equipment.

1.9.4 The Builder is to record on receipt the manufacturing date, or use-by date of critical materials. Any materials which have a shelf life are to be used in order of manufacturing date to ensure stock rotation.

1.9.5 The Builder is to establish and maintain a procedure to ensure that materials and consumables used in the hull construction process are identified (by colour-coding and/or marking as appropriate) from arrival in the yard through to fabrication in such a way as to enable the type and grade to be readily recognized.

1.9.6 Where materials are found to be defective they are to be rejected in accordance with the Builder's quality control procedure.

1.10 Faults

1.10.1 All identified faults are to be recorded under the requirements of the quality control systems. Faults are to be classified according to their severity and are to be monitored during periodical survey.

1.10.2 Production faults are to be discussed with the attending Surveyor and a rectification scheme agreed. Deviations from the approved plans are to be locally approved by the attending Surveyor and a copy forwarded to the plan approval office for record purpose.

1.11 Inspection

1.11.1 On acceptance of a 'Request for Services' the attending Surveyor is to inform the Builder of the key stages of the production that are to be inspected and the extent of the inspection to be carried out.

1.11.2 It is the Builder's responsibility to carry out required inspections in accordance with the accepted quality control system.

1.11.3 It is the Surveyor's responsibility to monitor the Builder's quality control records and carry out inspections at key stages and during periodic visits.

1.11.4 Adequate facilities are to be provided to enable the Surveyor to carry out a satisfactory inspection and to facilitate subsequent in-service maintenance. These are to include the provision of access holes in restricted spaces and removable deckhead and shipside linings, cabin soles, etc.

1.11.5 During inspections all deviations are to be dealt with in accordance with 1.6.4.

1.12 Acceptance criteria

1.12.1 Classification is dependent upon the work being carried out in accordance with the approved plans and the requirements of an accepted quality control system.

1.12.2 The work is to be carried out to the satisfaction of the attending Surveyor. This will include the verification of the quality control documentation and the remedial action associated with all defects and deficiencies recorded.

1.12.3 Proposed deviations from the approved plans are subject to LR approval and in the first instance are to be discussed with the attending Surveyor. Where applicable, an amended plan is to be submitted to the plan appraisal office. Such deviations will be recorded as endorsements to the certification unless specifically agreed otherwise with the plan appraisal office.

1.12.4 Where the above requirements are met the attending Surveyor will arrange for the relevant certification to be issued.

1.13 Repair

1.13.1 Minor repairs are to be agreed with the attending Surveyor and a rectification scheme agreed with the Builder. The Builder is to incorporate details of the agreed repair procedures in the quality control system in accordance with 1.6.4.

1.13.2 Repairs which affect the structural integrity are to be discussed with the Builder and the Builder's proposed rectification scheme is to be submitted to the plan appraisal office for consideration.

■ *Section 2* **Materials**

2.1 General

2.1.1 The materials used in the construction of the craft are to be manufactured and tested in accordance with the appropriate requirements of Chapter 8 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.2 As an alternative to 2.1.1, materials may be accepted for specific applications, provided they are manufactured and tested in accordance with the requirements of national or proprietary specifications which give reasonable equivalence to the requirements of the Rules for Materials. Additional tests may be required to prove that the materials are suitable for the intended purpose in respect of mechanical properties, weldability and corrosion resistance.

2.1.3 All materials are to be manufactured at works which have been approved by LR for the type and, where appropriate, grade of aluminium which is being supplied and for the relevant aluminium production and processing route.

2.2 Aluminium alloy plates, bars and sections

2.2.1 Materials are, in general, to be limited to the supply conditions detailed in Ch 8,1.6 of the Rules for Materials. Other supply conditions may be accepted but, as materials in a condition other than annealed are subject to a loss of mechanical strength in the vicinity of welded joints, the strength used in design calculations are to be as given in 2.4.

2.2.2 For applications where the material will be subject to high local stresses, it is recommended that the scantlings, when using higher strength materials, be determined on the basis of the mechanical properties of the material in the as-welded annealed condition.

2.3 Aluminium alloy castings

2.3.1 All structural castings are to be manufactured and tested in accordance with the appropriate requirements of Ch 8,3 of the Rules for Materials.

2.4 Mechanical properties for design

2.4.1 The minimum tensile strength properties of aluminium alloys approved for structural use are given in Table 2.2.1. Other alloys and conditions of temper may be accepted in accordance with 2.1.3.

2.4.2 In general, for welded structure, the maximum value for the strength of the material, σ_a, to be used in the scantling derivation is that of the aluminium alloy in the welded condition, where σ_a is defined as the 0,2 per cent butt welded proof stress or 70 per cent of the ultimate strength of the material in the welded condition in N/mm^2, whichever is the lesser.

2.4.3 The tensile modulus of elasticity to be used in scantling calculations is 69 x 10^3 N/mm^2 for all aluminium alloy materials.

2.4.4 The type of material, specification to which it is manufactured (including grade and temper) and minimum guaranteed mechanical properties are to be indicated on the construction drawings.

2.5 Cathodic protection

2.5.1 The potential of the aluminium-magnesium (5000 Series) and the aluminium-magnesium-silicon (6000 Series) alloys is generally in the range –0,7 to –0,9 Volts with reference to a silver/silver chloride sea-water reference electrode. A negative potential swing of at least 0,1 Volts from the corrosion potential is necessary to provide cathodic protection in sea-water (i.e. –0,8 to –1,0 Volts). The limit of negative potential is, however, not to exceed –1,1 Volts with reference to a silver/silver chloride sea-water reference electrode. Zinc or aluminium-zinc-indium or aluminium-zinc-tin anodes may be used for cathodic protection but aluminium anodes containing mercury are not acceptable.

2.5.2 Where an impressed current cathodic protection system is fitted, plans showing the proposed layout of anodes and hull penetrations are to be submitted.

2.6 Paints and coatings

2.6.1 The hull, deck, deckhouse and superstructure and other structure which is exposed to the marine environment is to be protected against corrosion by a suitable protective coating. All coatings are to be in accordance with the requirements of this Section. Internal structure need not in general be coated provided that they are built of aluminium alloy grades shown in Chapter 8 of the Rules for Materials.

Table 2.2.1 Minimum mechanical properties for aluminium alloys

Alloy	Condition		0,2% proof stress N/mm^2		Ultimate tensile strength N/mm^2	
			Unwelded	Welded (*see* Note 4)	Unwelded	Welded (*see* Note 4)
5083	O/H111		125	125	275	275
5083	H112		125	125	275	275
5083	H116/H321		215	125	305	275
5383	O/H111		145	145	290	290
5383	H116/H321		220	145	305	290
5086	O/H111		100	95	240	240
5086	H112		125 (*see* Note 2)	95	250 (*see* Note 2)	240
5086	H116/H321		195	95	275	240
5059	O/H111		160	160	330	330
5059	H116/H321		260	160	360	300
5456	O		125	125	285	285
5456	H116		200 (*see* Note 5)	125	290 (*see* Note 5)	285
5456	H321		215 (*see* Note 5)	125	305 (*see* Note 5)	285
5754	O/H111		80	80	190	190
6005A (*see* Note 1)	T5/T6	Extruded: Open Profile Extruded: Closed Profile	215 215	100 100	260 250	160 160
6061 (*see* Note 1)	T5/T6	Rolled Extruded: Open Profile Extruded: Closed Profile	240 240 205	125 125 125	290 260 245	160 160 160
6082	T5/T6	Rolled Extruded: Open Profile Extruded: Closed Profile	240 260 240	125 125 125	280 310 290	190 190 190

NOTES
1. These alloys are not normally acceptable for application in direct contact with sea-water.
2. *See also* Table 8.1.4 in Chapter 8 of the Rules for Materials.
3. The mechanical properties to be used to determine scantlings in other types and grades of aluminium alloy manufactured to national or proprietary standards and specifications are to be individually agreed with LR, *see also* Ch 8,1.1.5 of the Rules for Materials.
4. Where detail structural analysis is carried out, 'Unwelded' stress values may be used away from heat-affected zones and weld lines, *see also* Ch 3,1.9.1 and 1.10.1 to 1.10.3.
5. For thickness less than 12,5 mm the minimum unwelded 0,2% proof stress is to be taken as 230 N/mm^2 and the minimum tensile strength is to be taken as 315 N/mm^2.

2.6.2 Aluminium alloy is to be suitably cleaned, cleared of oxide and degreased before the application of any protective coating.

2.6.3 Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used. Coatings are to be of adequate film thickness, applied in accordance with the paint manufacturer's specification. The paint or coating is to be compatible with any previously applied primer.

2.6.4 Paints containing lead, mercury or copper are not to be used in conjunction with aluminium alloys.

2.6.5 Paints, varnishes and similar preparations having a nitro-cellulose or other highly flammable base are not to be used in accommodation or machinery spaces.

2.7 Galvanic action

2.7.1 Where bimetallic connections are made, involving dissimilar metals, measures are to be incorporated to preclude galvanic corrosion. In order to prevent galvanic corrosion, special attention is to be given to the penetrations of and connections to the hull, bulkheads and decks by piping and equipment where dissimilar materials are involved.

2.8 Bimetallic connections

2.8.1 The design is to ensure that the location of all bimetallic connections allows for regular inspection and maintenance of the joints and penetrations during service.

2.9 Deck coverings

2.9.1 Where plated decks are sheathed with wood, the sheathing is to be efficiently attached to the deck, caulked and sealed, to the satisfaction of the Surveyor in accordance with the approved drawings.

2.9.2 Deck coverings in the following positions are to be of a type which will not readily ignite where used on decks:

(a) Forming the crown of machinery or cargo spaces within accommodation spaces of cargo craft.

(b) Within accommodation spaces, control stations, stairways and corridors of passenger craft.

2.10 Corrosion margin

2.10.1 The scantlings determined from the formulae provided in the Rules assume that the materials used are selected, manufactured and protected in such a way that there is negligible loss in strength by corrosion.

2.10.2 Where aluminium alloy is not protected against corrosion, by painting or other approved means, the scantlings may require to be further considered.

2.11 Fracture control

2.11.1 Aluminium alloys in commercial use are in general not subject to unstable crack growth in an elastic stress field because fracture toughness is high. However, for alloys with higher strength and/or temper, special tests may be required to provide information on fracture toughness.

2.11.2 Construction procedures, materials and welding are to be in accordance with the requirements of this Chapter such that stress corrosion cracking is avoided.

2.11.3 High local stresses are to be avoided by the use of suitable design detail, *see also* LR's *Guidance Notes for Structural Details*.

■ *Section 3*
Procedures for welded construction

3.1 General

3.1.1 The requirements of this Section are applicable to aluminium alloys welded using the metal inert gas (MIG) or tungsten inert gas (TIG) processes. Where it is proposed to use alternative welding processes, details are to be submitted for approval, prior to the start of fabrication.

3.2 Information to be submitted

3.2.1 The plans and information submitted for approval are to clearly indicate details of the welded connections of the main structural members, including the type, disposition and size of welds.

3.3 Welding equipment

3.3.1 Welding plant and appliances are to be suitable for the purpose intended and are to be maintained in an efficient condition. Suitable earthing arrangements are to be provided when welding is being carried out. Satisfactory storage facilities for consumables are to be provided close to working areas.

3.4 Welding consumables

3.4.1 All welding consumables are to be approved by LR and are to be suitable for the type of joint and grade of material, *see* Ch 11,9 of the Rules for Materials.

3.4.2 The 5083 and 5086 alloys are normally welded using the 5356, 5556 or 5183 consumables and the 6061 and 6082 alloys are normally welded using the 4043 consumables.

3.4.3 Only approved filler wires are to be used. Testing requirements for welding consumables are contained in the Rules for Materials.

3.4.4 Cast aluminium alloys are not in general to be welded directly to wrought high magnesium alloys unless the welding is carried out in accordance with an agreed procedure.

3.4.5 Special care is to be taken in the distribution, storage and handling of all welding consumables. Aluminium filler metals are to be kept in a heated dry storage area with a relatively uniform temperature. Condensation on the metal surface during storage and use is to be avoided. Other welding consumables such as bare wire and welding studs are to be stored under dry conditions to prevent corrosion. Effective facilities for protecting consumables are to be provided close to working areas.

3.5 Welder qualifications

3.5.1 Welding operators are to be proficient in the type of work on which they are engaged.

3.5.2 The responsibility for selection, training and testing of welding operators rests with the Builders. The Builders are to test welding operators to a suitable National Standard. Records of tests and qualifications are to be kept by the Builders and made available to the Surveyors so that they can be satisfied that the personnel employed during the construction of the craft can achieve the required standard of workmanship.

3.6 Welding procedures

3.6.1 Procedures are to be established for the welding of all joints including the type of consumables, joint preparation and welding position. New procedures will be approved on the basis of a detailed statement of the procedure and process parameters together with the results of examination and testing carried out on sample joints in the presence of the Surveyor. For this purpose, the sample joints are to be prepared under conditions similar to those which will occur during construction of the craft.

3.6.2 The approved arrangements, sequence and procedures are not to be departed from without the prior approval of the Surveyor.

3.6.3 The type and diameter of filler wire, the current, voltage, rate of deposit and number of runs, etc., are to conform to those established in accordance with 3.18.1. Provision is to be made for checking the above parameters at the welding area.

3.6.4 When required, weld repairs are to be carried out in accordance with the procedures laid down in 3.19.

3.7 Defined practices and welding sequence

3.7.1 Details of the welding procedures (*see* 3.6) and the sequence of welding assemblies and joining up of assemblies are to be submitted.

3.7.2 The proposed sequence of welding is to be agreed with the Surveyor prior to construction.

3.7.3 The type and disposition of connections and sequences of welding are to be so planned that any restraint during welding operations is reduced to a minimum.

3.7.4 Special attention is to be given to the examination of plating in way of all lifting eye plate positions to ensure freedom from cracks. This examination is not restricted to the positions where eye plates have been removed but includes the positions where lifting eye plates are permanent fixtures.

3.7.5 Careful consideration is to be given to assembly sequence and overall shrinkage of plate panels, assemblies, etc., resulting from welding processes employed. Welding is to proceed systematically with each welded joint being completed in correct sequence without undue interruption. Where practicable, welding is to commence at the centre of a joint and proceed outwards or at the centre of an assembly and progress outwards towards the perimeter so that each part has freedom to move in one or more directions. Generally, the welding of stiffener members including transverses, frames, girders, etc., to welded plate panels by automatic processes is to be carried out in such a way as to minimise angular distortion of the stiffener.

3.7.6 Butt welds are to be finished full at the ends and cut back before welding the seams. Seams are generally not to be welded within 300 mm of an unwelded butt weld or welded across an unwelded butt joint.

3.7.7 The final boring out of propeller brackets and sterntubes and the fit-up and alignment of rudder bearings and jet units are to be carried out after the major part of the welding of the aft end of the craft is complete. The contacts between rudder stocks and propeller shafts with bearings are to be checked before the final mounting.

3.7.8 Precautions are to be taken to screen and pre-warm the general and local weld areas as necessary. Surfaces are to be dry.

3.8 Shipyard practices

3.8.1 A sufficient number of skilled supervisors is to be provided to ensure an effective and systematic control at all stages of welding operations.

3.9 Welding environment

3.9.1 Adequate protection is to be provided where welding is required to be carried out in exposed positions in wet, windy or cold weather. In cold weather, precautions are to be taken to pre-warm the work and screen where necessary to prevent too rapid cooling of the weld.

3.9.2 Special precautions are to be taken to protect the building area from contamination by dissimilar metals (e.g. iron, steel and copper).

3.10 Structural arrangements and access

3.10.1 Ceilings, cabin sole, side and overhead linings are to be secured in such a manner as to be easily removed for the maintenance and inspection of the structure below.

3.10.2 Structural arrangements are to be such as will allow adequate ventilation and access for preheating, where required, and for the satisfactory completion of all welding operations. Welded joints are to be so arranged as to facilitate the use of downhand welding wherever possible.

3.11 Preparation

3.11.1 The preparation of plate edges is to be accurate and essentially free from blemishes. All joints are to be properly aligned and closed or adjusted before welding. Excessive force is not to be used in fairing and closing the work. Means are to be provided for holding the work in proper alignment without rigid restraint during welding operations. Where excessive gaps exist between surfaces or edges to be joined, the corrective measures adopted are to be to the satisfaction of the Surveyor.

3.11.2 Parts are to be set up and welded in such a way that contraction stresses are kept to a minimum.

3.11.3 Before a manual sealing run is applied to the back of a weld the original root run is to be cut back to sound metal.

3.11.4 Welding is to proceed systematically, each welded joint being completed in proper sequence without undue interruption.

3.11.5 Joint edges are to be scratch brushed (or other acceptable method), immediately before welding, in order to remove oxide or adhering films of dirt and filings.

3.12 Cleanliness

3.12.1 The surfaces in way of all parts to be welded are to be clean, dry and free from grease and other contaminants which might adversely affect weld quality by cleaning with suitable chemicals or solvents.

3.13 Heat treatment

3.13.1 Under conditions of high humidity, the parts to be welded are to be preheated.

3.13.2 Where the parts to be welded are large such that heat conduction prevents the joint from reaching the required temperature, or where the parts to be welded are below 5°C, preheating is to be used.

3.13.3 For aluminium-magnesium alloys, the preheating temperature is to be limited to 60°C to avoid the risk of stress corrosion cracking.

3.13.4 With the 6000 series heat-treatable alloys, it is sometimes beneficial to apply a post-weld heat treatment in the form of artificial ageing. The procedure to be used depends on the alloy and, in order to quantify the benefits, tests are required using representative specimens which accurately simulate the true situation in terms of metal thickness, geometry, filler metal and welding parameters, as well as the post-weld treatment employed.

3.14 Tack welding

3.14.1 Consumables for tack welding are to be of the same grade as those used for the main weld.

3.14.2 Tack welds are to be kept to the minimum and are generally not to be applied in lengths of less than 40 mm. They are to be of equal quality to the finished weld.

3.14.3 Tack welds which are to be retained as part of the finished weld are to be clean and free from defects before being incorporated into the weld. Care is to be taken when removing tack welds used for assembly to ensure that the material of the structure is not damaged.

3.15 Alignment and fit

3.15.1 All joints are to be prepared, aligned and adjusted in accordance with the established joint design. Clamps with wedges or strong-backs used for this purpose are to be suitably arranged to allow freedom of lateral movement between adjacent elements.

3.15.2 Welded temporary attachments used to aid construction are to be removed carefully by grinding, cutting or chipping. The surface of the material is to be finished smooth by grinding followed by crack detection.

3.15.3 Any defects in the structure resulting from the removal of temporary attachments are to be prepared, efficiently welded and ground smooth so as to achieve a defect free repair.

3.16 Inspection

3.16.1 Effective arrangements are to be provided by the Builder for the visual inspection of finished welds in order to ensure that all welding has been satisfactorily completed.

3.17 Testing

3.17.1 Welds are to be clean and free from paint at the time of inspection.

3.17.2 In addition to visual inspection, welded joints are to be examined using any one or a combination of ultrasonic, radiographic, magnetic particle, eddy current, dye penetrant or other acceptable methods appropriate to the configuration of the weld.

3.17.3 The method to be used for the volumetric examinations of welds is the responsibility of the Builder. Radiography is generally to be used on butt welds of 15 mm thickness or less. Ultrasonic testing is acceptable for welds of 15 mm thickness or greater and is to be used for the examination of full penetration tee butt or cruciform welds or joints of similar configuration.

3.17.4 Non-destructive examinations are to be made in accordance with approved written procedures prepared by the Builder, which identify the method and technique to be used, the extent of the examination and the acceptance criteria to be applied.

3.17.5 Non-destructive examinations are to be undertaken by personnel qualified to the appropriate level of a certification scheme recognized by LR.

3.17.6 Checkpoints examined at the pre-fabrication stage are to include ultrasonic testing on examples of the stop/start points of automatic welding and magnetic particle inspections of weld ends.

3.17.7 Checkpoints examined at the construction stage are generally to be selected from those welds intended to be examined as part of the agreed quality control programme to be applied by the Builder. The locations and numbers of checkpoints are to be agreed between the Builder and the Surveyor.

3.17.8 Particular attention is to be paid to highly stressed items. Magnetic particle inspection is to be used at ends of fillet welds, T-joints, joints or crossings in main structural members and at sternframe connections.

3.17.9 Checkpoints for volumetric examination are to be selected so that a representative sample of welding is examined.

3.17.10 Typical locations for volumetric examination and number of checkpoints to be taken are shown in Table 2.3.1. A list of the proposed items to be examined is to be submitted for approval.

3.17.11 For the hull structure of refrigerated spaces and of craft designed to operate in low air temperatures, the extent of non-destructive examination will be specially considered.

3.17.12 For all craft types, the Builder is to carry out random non-destructive examination at the request of the Surveyor.

3.17.13 The full extent of any weld defect is to be ascertained by applying additional non-destructive examinations where required. Unacceptable defects are to be completely removed and where necessary, re-welded. The repair is to be examined after re-welding, *see* 3.19.

3.17.14 Results of non-destructive examinations made during construction are to be recorded and evaluated by the Builder on a continual basis in order that the quality of welding can be monitored. These records are to be made available to the Surveyors.

3.17.15 The extent of applied non-destructive examinations is to be increased when warranted by the analysis of previous results.

3.18 Acceptance criteria

3.18.1 All finished welds are to be sound and free from cracks and substantially free from lack of fusion, incomplete penetration, porosity and tungsten inclusions. The surfaces of welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and underfill of welds are avoided.

3.18.2 The quality and workmanship of welding of all fittings and attachments to main structure, both permanent and temporary, are to be equivalent to those of the main hull structure.

3.18.3 Visual examination of all welds is to be supplemented by non-destructive testing as considered necessary by the Surveyor.

Table 2.3.1 Non-destructive examinations of welds

Volumetric non-destructive examinations – Recommended extent of testing, *see* 3.17.10		
Item	Location	Checkpoints, *see* Note 1
Intersections of butts and seams of fabrication and section welds	Throughout: hull envelope longitudinal and transverse bulkheads inner bottom and hopper bottom	The summation of checkpoint lengths (*see* Note 2) examined at intersections is to be *L*, where *L* is the overall length of the ship in metres
Butt welds in plating	Throughout	1 m in 25 m (*see* Note 3)
Seam welds in plating	Throughout	1 m in 100 m
Butts in longitudinals	Hull envelope within 0,4*L* amidships Hull envelope outside 0,4*L* amidships	1 in 10 welds 1 in 20 welds
Bilge keel butts	Throughout	1 in 10 welds
Structural items when made with full penetration welding as follows: connection of stool and bulkhead to lower stool shelf plating vertical corrugations to an inner bottom hopper knuckles sheerstrake to deck stringer hatchways coaming to deck	Throughout	1 m in 20 m

NOTES
1. The length of each checkpoint is to be between 0,3 m and 0,5 m.
2. For checkpoints at intersections the measured dimension of length is to be in the direction of the butt weld.
3. Checkpoints in butt welds and seam welds are in addition to those at intersections.
4. Agreed locations are not to be indicated on the blocks prior to the welding taking place, nor is any special treatment to be given at these locations.
5. Particular attention is to be given to repair rates in longitudinal butts. Additional welds are to be tested in the event that defects, such as lack of fusion or incomplete penetrations, are repeatedly observed.

3.18.4 Fairing, by linear or spot heating, to correct distortions due to welding is, in general, not to be carried out unless procedures have been approved to ensure that the properties of the material are not adversely affected. Visual examination of all heat affected areas and welds in the vicinity is to be carried out to ensure freedom from defects.

3.19 Weld repair

3.19.1 Repairs to defective welding are to be carried out using approved welding consumables and procedures. The repair is to be re-examined for further defects.

3.19.2 Tears and scars left on plating after the removal of temporary lifting lugs, cleats and other temporary fittings or attachments are to be built up by welding if necessary and dressed smooth.

3.19.3 When modifications or repairs have been made which result in openings having to be closed by welded inserts, particular care is to be given to the fit of the insert and the welding sequence. The welding is also to be subject to non-destructive testing.

3.19.4 When misalignment of structural members either side of bulkheads, decks, etc., exceeds the agreed tolerance, the misaligned item is to be released, realigned and rewelded in accordance with an approved weld repair procedure, *see also* Pt 3, Ch 1,8.

3.20 Structural detail

3.20.1 Alignment of structure is to be in accordance with 3.15. Triaxial stresses are to be avoided, *see also* LR's *Guidance Notes for Structural Details*.

■ *Section 4*
Joints and connections

4.1 General

4.1.1 Requirements are given in this Chapter for welding connection details, aluminium/steel transition joints, aluminium/wood connection, riveting of light structure and chemical bonding.

4.1.2 Welded joints are to be detailed such that crevices or inaccessible pockets capable of retaining dirt or moisture are avoided. Where cavities are unavoidable, they are to be sealed by welding or protective compounds or made accessible for inspection and maintenance.

4.2 Weld symbols

4.2.1 Weld symbols, where used, are to conform to a recognised National or International Standard. Details of such Standards are to be indicated on the welding schedule, which is to be submitted for appraisal.

4.3 Welding schedule

4.3.1 A welding schedule containing not less than the following information is to be submitted:
(a) Weld throat thickness or leg lengths.
(b) Grades, tempers, and thicknesses of materials to be welded.
(c) Locations, types of joints and angles of abutting members.
(d) Reference to welding procedures to be used.
(e) Sequence of welding of assemblies and joining up of assemblies.

4.4 Butt welds

4.4.1 All structural butt joints are to be made by means of full penetration welds and, in general, the edges of plates to be joined by welding are to be bevelled on one or both sides of the plates. Full details of the proposed joint preparation are to be submitted for approval, *see also* 4.24.

4.4.2 Abrupt change of section is to be avoided where plates of different thicknesses are to be butt welded. Where the difference in thickness exceeds 3 mm, the thicker plate to be welded is to be prepared with a taper not exceeding one in three or with a bevelled edge to form a welded joint proportioned correspondingly. Where the difference in thickness is less than 3 mm the transition may be achieved within the width of the weld. Difference in thickness greater than 3 mm may be accepted provided it can be proven by the Builder, through procedure tests, that the Rule transition shape can be achieved and that the weld profile is such that structural continuity is maintained to the Surveyor's satisfaction.

4.4.3 Where stiffening members are attached by continuous fillet welds and cross completely finished butt or seam welds, these welds are to be made flush in way of the faying surface. Similarly, for butt welds in webs of stiffening members, the butt weld is to be completed and generally made flush with the stiffening member before the fillet weld is made. The ends of the flush portion are to run out smoothly without notches or sudden change of section. Where these conditions cannot be complied with, a scallop is to be arranged in the web of the stiffening member. Scallops are to be of such size, and in such a position, that a satisfactory weld can be made.

4.4.4 Where butt welds form a T-junction, the leg of the T is, where practicable, to be completed first including any back run. During the welding operation special attention is to be given to the completion of the weld at the junction, which is to be chipped back to remove crater cracks, etc., before the table is welded.

4.4.5 For guidance purposes, a number of typical joint preparations for TIG and MIG welding are shown in Tables 2.4.1 and 2.4.2 respectively.

Table 2.4.1 Typical joint preparations for TIG welding of aluminium alloys

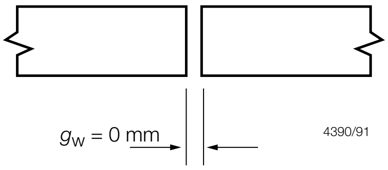
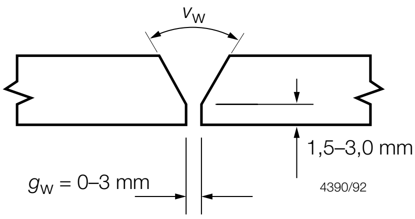
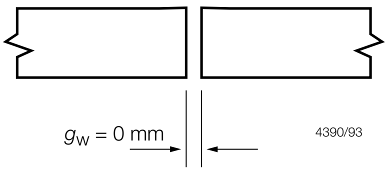
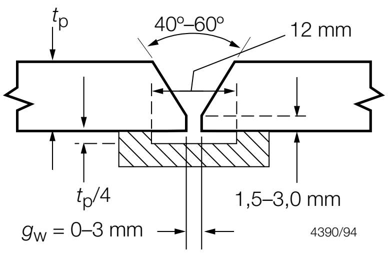
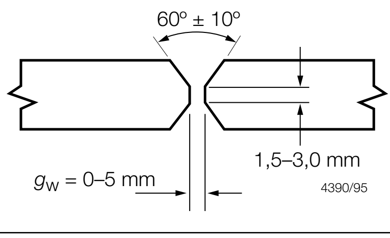
Thickness (mm)	Joint design	Welding position/comments
2,5 – 3,0		Flat Horizontal Vertical Overhead
3,0 – 10,0		Flat and Vertical V = 60° Horizontal and Overhead V = 90° – 110°
Symbols and definitions		
g_W = weld gap, in mm V_W = weld preparation angle, in degrees		

Table 2.4.2 Typical joint preparations for semi-automatic MIG welding

Thickness (mm)	Joint design	Welding position/comments
5,0 – 6,5		Flat
7,0 – 15,0		Flat Horizontal Vertical Overhead One sided welding with temporary backing
12,0 – 25,0		All positions
Symbols and definitions		
t_p = plate thickness, in mm g_W = weld gap, in mm		

4.5 Fillet welds

4.5.1 T-connections are generally to be made by fillet welds on both sides of the abutting plate, the dimensions and spacing of which are shown in Fig. 2.4.1. Where the connection is highly stressed full penetration welding may be required. Where full penetration welding is required, the abutting plate may need to be bevelled.

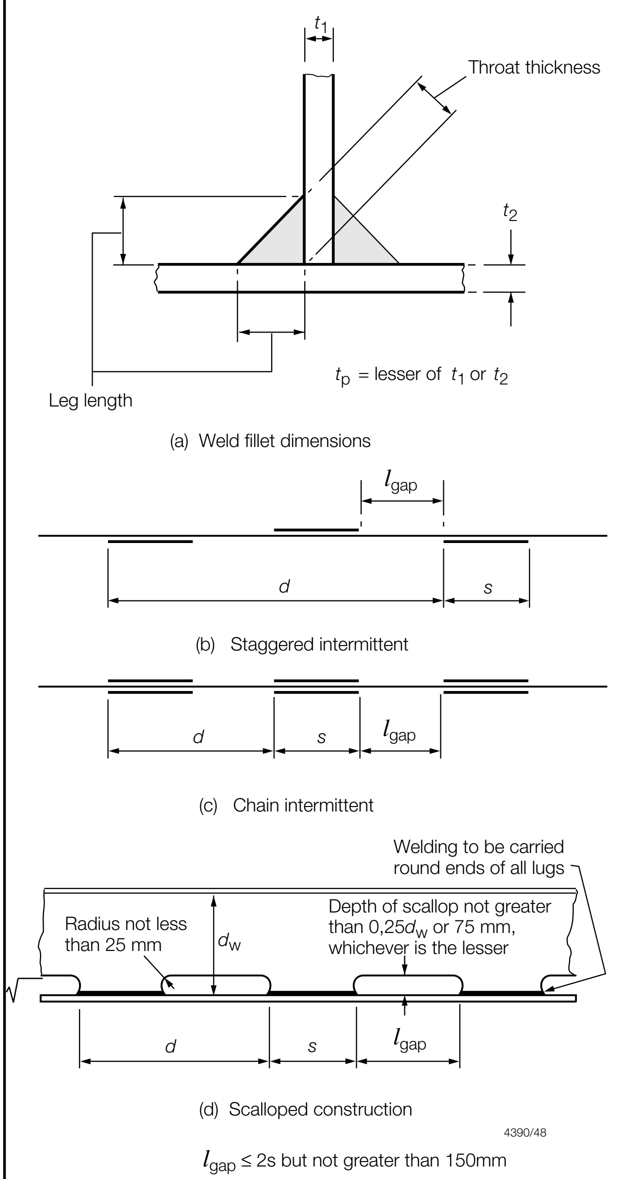


Fig. 2.4.1 Weld types

4.5.2 The throat thickness of fillet welds is to be determined from:

$$\text{Throat thickness} = t_p \times \text{Weld factor} \times \left(\frac{d}{s}\right) \text{ mm}$$

where

s = the length of correctly proportioned weld fillet, clear of end craters, in mm, and is to be 10 x plate thickness, t_p, or 75 mm, whichever is the lesser, but in no case to be taken less than 40 mm

d = the distance between successive weld fillets, in mm

t_p = plate thickness, in mm, on which weld fillet size is based, *see* 4.5.6.

Weld factors are contained in Table 2.4.3.

NOTE:

for double continuous fillet welding $\left(\frac{d}{s}\right)$ is to be taken as 1 (*see* 4.8.1).

4.5.3 For ease of welding, it is recommended that the ratio of the web height to the flange breadth be greater than or equal to 1,5 (*see* Fig. 2.4.2).

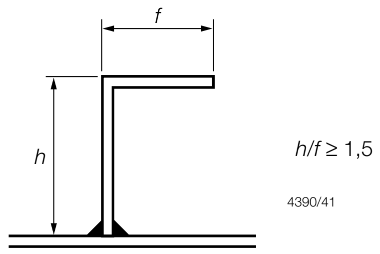


Fig. 2.4.2 Web height/flange breadth ratio

4.5.4 Where an approved automatic deep penetration procedure is used, the weld factors given in Table 2.4.3 may generally be reduced by 15 per cent. Consideration may be given to reductions of up to 20 per cent provided that the Shipyard is able to consistently meet the following requirements:

(a) Suitable process selection confirmed by welding procedure tests covering both minimum and maximum root gaps.

(b) Demonstrate, to the satisfaction of the Surveyor, that an established quality control system is in place.

4.5.5 The leg length of the weld is to be not less than twice the specified throat thickness.

4.5.6 The plate thickness t_p to be used in 4.5.2 is generally to be that of the thinner of the two parts being joined. Where the difference in thickness is considerable, the size of fillet will be specially considered.

4.6 Throat thickness limits

4.6.1 The throat thickness limits given in Table 2.4.4 are to be complied with.

Table 2.4.3 Weld factors (*see continuation*)

Item	Weld Factor	Remarks
(1) General application:		except as required below
(a) Watertight plate boundaries	0,34	
(b) Non-tight plate boundaries	0,13	
(c) Longitudinals, frames, beams, and other secondary members to shell, deck, or bulkhead plating	0,10 0,13 0,21	 in tanks in way of end connections
(d) Panel stiffeners	0,10	
(e) Overlap welds generally	0,27	
(f) Longitudinals of the flat-bar type to plating		*see* 4.8.2
(2) Bottom construction:		
(a) Non-tight centre girder: • to keel • to inner bottom	 0,27 0,21	 no scallops
(b) Non-tight boundaries of: • floors, girders and • brackets	 0,21 0,27	 in way of 0,2 x span at ends in way of brackets at lower end of main frame
(c) Inner bottom longitudinals, or face flat to floors reverse frames	0,13	
(d) Connection of floors to inner bottom where bulkhead supported on tank top. The supporting floors are to be continuously welded to the inner bottom	0,44	Weld size based on floor thickness Weld material compatible with floor material
(3) Hull framing:		
(a) Webs of web frames and stringers: • to shell • to face plate	 0,16 0,13	
(4) Decks and supporting structure:		
(a) Weather deck plating to shell Other decks to shell and bulkheads (except where forming tank boundaries)	0,44 0,21	 generally continuous
(b) Webs of cantilevers to deck and to shell in way of root bracket	0,44	
(c) Webs of cantilevers to face plate	0,21	
(d) Girder webs to deck clear of end brackets	0,10	
(e) Girder webs to deck in way of end brackets	0,21	
(f) Web of girder to face plate	0,10	
(g) Pillars: • fabricated • end connections • end connections (tubular)	 0,10 0,34 full penetration	
(h) Girder web connections and brackets in way of pillar heads and heels	0,21	continuous

Table 2.4.3 Weld factors (*see continuation*)

Item	Weld Factor	Remarks
(5) Bulkheads and tank construction:		
(a) Plane and corrugated watertight bulkhead boundary at bottom, bilge, inner bottom, deck and connection to shelf plate, where fitted	0,44	Weld size to be based on thickness of bulkhead plating Weld material to be compatible with bulkhead plating material
(b) Secondary members where acting as pillars	0,13	
(c) Non-watertight pillar bulkhead boundaries	0,13	
(d) Perforated flats and wash bulkhead boundaries	0,10	
(e) Deep tank horizontal boundaries at vertical corrugations	full penetration	
(6) Structure in machinery space:		
(a) Centre girder to keel and inner bottom	0,27	no scallops to inner bottom
(b) Floors to centre girder in way of engine thrust bearers	0,27	
(c) Floors and girders to shell and inner bottom	0,21	
(d) Main engine foundation girders: • to top plate • to hull structure	deep penetration to depend on design	edge to be prepared with maximum root $0{,}33t_p$ deep penetration, generally
(e) Floors to main engine foundation girders	0,27	
(f) Brackets, etc., to main engine foundation girders	0,21	
(g) Transverse and longitudinal framing to shell	0,13	
(7) Superstructures and deckhouses:		
(a) Connection of external bulkheads to deck	0,34 0,21	1st and 2nd tier erections elsewhere
(b) Internal bulkheads	0,13	
(8) Steering control systems:		
(a) Rudder: • Fabricated mainpiece and • mainpiece to side plates and webs	0,44	
(b) Slot welds inside plates	0,44	
(c) Remaining construction	0,21	
(d) Fixed and steering nozzles: • Main structure • Elsewhere	 0,44 0,21	
(e) Fabricated housing and structure of thruster units, stabilisers, etc.: • Main structure • Elsewhere	 0,44 0,21	

Table 2.4.3 Weld factors (*conclusion*)

Item	Weld Factor	Remarks
(9) Miscellaneous fittings and equipment:		
(a) Rings for manhole type covers, to deck or bulkhead	0,34	
(b) Frames of shell and weathertight bulkhead doors	0,34	
(c) Stiffening of doors	0,21	
(d) Ventilator, air pipes, etc., coamings to deck	0,34 0,21	Load Line Positions 1 and 2 elsewhere
(e) Ventilator, etc., fittings	0,21	
(f) Scuppers and discharges, to deck	0,44	
(g) Masts, crane pedestals, etc., to deck	0,44	full penetration welding may be required
(h) Deck machinery seats to deck	0,21	generally
(j) Mooring equipment seats	0,21	generally, but increased or full penetration may be required
(k) Bulwark stays to deck	0,21	
(l) Bulwark attachment to deck	0,34	
(m) Guard rails, stanchions, etc., to deck	0,34	
(n) Bilge keel ground bars to shell	0,34	continuous fillet weld, minimum throat thickness 4 mm
(o) Bilge keels to ground bars	0,21	light continuous or staggered intermittent fillet weld, minimum throat thickness 3 mm
(p) Fabricated anchors		full penetration

4.7 Single sided welding

4.7.1 Where the main welding is carried out from one side only a back sealing run is to be applied to all butt welds, after suitable back gouging, unless the welding process and consumables have been specially approved for one-side welding.

4.7.2 Where internal access for welding is impracticable, backing bars are to be fitted in way of butt and fillet welds, or alternative means of obtaining full penetration welds are to be agreed. Backing bars may be permanent or temporary.

4.7.3 Permanent backing bars are to be of the same material as the base metal and of thickness not less than the thickness of the plating being joined or 4 mm, whichever is the lesser. The weld is to be thoroughly fused to the backing bar.

4.7.4 Backing bars are to be continuous for the full length of the weld and joints in the backing bar are to be by full penetration welds, ground smooth.

4.7.5 Temporary backing bars for single sided welding may be austenitic stainless steel, glass tape, ceramic, or anodised aluminium of the same material as the base metal. Backing bars are not to be made of copper to avoid weld contamination and corrosion problems.

4.7.6 Temporary backing bars are to be suitably grooved in way of the weld to ensure full penetration.

4.8 Double continuous welding

4.8.1 Where double continuous fillet welding is proposed the throat thickness is to be in accordance with 4.5.2 taking $\left(\frac{d}{s}\right)$ equal to 1.

4.8.2 Double continuous welding is to be adopted in the following locations and may be used elsewhere if desired:

(a) Boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings.
(b) Boundaries of tank and watertight compartments.
(c) Main engine seatings.
(d) Bottom framing structure of high speed craft in way of machinery and jet room spaces as appropriate.
(e) The side and bottom shell structure in the impact area of high speed motor craft.
(f) The underside of the cross-deck structure in the impact area of high speed multi-hull craft.
(g) Structure in way of ride control systems, stabilisers, thrusters, bilge keels, foundations and other areas subject to high stresses.

Table 2.4.4 Throat thickness limits

Item	Throat thickness mm	
	Minimum	Maximum
(1) Double continuous welding	$0{,}21t_p$	$0{,}44t_p$
(2) Intermittent welding	$0{,}27t_p$	$0{,}44t_p$ or 4,5
(3) Overriding minimum:		
(a) Continuous welds	2,5	
(b) Intermittent welds:		
(i) Plate thickness $t_p \leq 7{,}5$ mm Hand or automatic welding	3,0	
Automatic deep penetration welding	3,0	
(ii) Plate thickness $t_p \geq 7{,}5$ mm Hand or automatic welding	3,25	
Automatic deep penetration welding	3,0	

NOTES
1. In all cases the limiting maximum value is to be taken as the greatest of the applicable values above.
2. The maximum throat thicknesses shown are intended only as a design limit for the approval of fillet welded joints. Any welding in excess of these limits is to be to the Surveyor's satisfaction.

(h) The shell structure in the vicinity of the propeller blades.
(j) Stiffening members to plating in way of end connections scallops and of end brackets to plating in the case of lap connections.
(k) Primary and secondary members to plating in way of end connections, and end brackets to plating in the case of lap connections.
(l) Face flats to webs of built-up/fabricated stiffening members in way of knees/end brackets and for a distance beyond such knees/end brackets of not less than the web depth of stiffener in way.

4.9 Full penetration welding

4.9.1 Where full penetration welding is required in accordance with 4.4 and 4.5, these are to be made by welding from both sides with the root of the first weld back gouged to sound metal before welding the second side. The weld on the second side may be a sealing run.

4.9.2 Where access to the second side for welding is impracticable, backing bars are to be used in accordance with 4.7.

4.10 Intermittent welding (staggered)

4.10.1 Where intermittent welding is used, the welding is to be made continuous round the ends of brackets, lugs, scallops, etc.

4.10.2 Staggered intermittent welding may be used, outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.11 Intermittent welding (chain)

4.11.1 Chain intermittent welding may be used, outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.12 Slot welding

4.12.1 For the connection of plating to internal webs where access for welding is not practicable, the closing plating is to be attached by continuous full penetration welds, or by slot fillet welds to face plates fitted to the webs. Slots are, in general, to have a minimum length of ten times the plating thickness or 75 mm, whichever is the lesser, but in no case to be taken as less than 40 mm, and a minimum width of twice the plating thickness or 15 mm whichever is the greater, with well rounded ends. Slots cut in plating are to have smooth, clean and square edges and the distance between the slots is, in general, not to exceed 150 mm. Slots are not to be filled with welding. Alternative proposals for length, width and spacing of slot welds will be specially considered.

4.13 Stud welding

4.13.1 Where permanent or temporary studs are to be attached by welding to main structural parts in areas subject to high stress, the proposed location of the studs and the welding procedures adopted are to be to the satisfaction of the Surveyors.

4.14 Lap connections

4.14.1 Overlaps are generally not to be used to connect plates which may be subjected to high tensile or compressive loading and alternative arrangements are to be considered. Where, however, plate overlaps are adopted, the width of the overlap is not, in general, to exceed four times nor be less than three times the thickness of the thinner plate and the joints are to be positioned so as to allow adequate access for completion of sound welds. The faying surfaces of lap joints are to be in close contact and both edges of the overlap are to have continuous fillet welds.

4.15 Connections of primary structure

4.15.1 Depending on the structural design of the joint and design loads on the primary member, full penetration welding of flanges and web plates may be required to attain full section properties in the end connections of primary members. *See also* Pt 6, Ch 3,1.22. Otherwise weld factors for the connections of primary structure are given in Table 2.4.3.

4.15.2 The weld connection to shell, deck or bulkhead is to take account of the material lost in the notch where longitudinals or stiffeners pass through the member. Where the width of notch exceeds 15 per cent of the stiffener spacing, the weld factor is to be multiplied by:

$$\frac{0{,}85 \text{ x stiffener spacing}}{\text{length of web plating between notches}}$$

4.15.3 Where direct calculation procedures have been adopted, the weld factors for the 0,2 x overall length at the ends of the members will be considered in relation to the calculated loads.

4.16 Primary and secondary member end connection welds

4.16.1 Welding of end connections of primary members is to be such that the area of welding is not less than the cross-sectional area of the member, and the weld factor is to be not less than 0,34 in tanks or 0,27 elsewhere.

4.16.2 The welding of secondary member end connections is to be not less than as required by Table 2.4.5. Where two requirements are given the greater is to be complied with.

4.16.3 The area of weld, A_w, is to be applied to each arm of the bracket or lapped connection.

4.16.4 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the area of weld is to be not less than the cross-sectional area of the member.

4.17 Weld connection of strength deck plating to sheerstrake

4.17.1 The weld connection of strength deck plating to sheerstrake is to be by double continuous fillet welding with a weld factor of 0,44. The welding procedure, including joint preparation, is to be specified and the procedure qualified and approved for individual Builders.

4.18 Air and drain holes

4.18.1 Air and drain holes are to be kept clear of the toes of brackets, etc. Openings are to be well rounded with smooth edges, *see also* LR's *Guidance Notes for Structural Details*.

4.19 Notches and scallops

4.19.1 Notches and scallops are to be kept clear of the toes of brackets, etc. Openings are to be well rounded with smooth edges. Details of scallops are shown in Fig. 2.4.1.

4.19.2 Scallops are to be of such a size, and in such a position that a satisfactory weld can be made around the ends of openings.

4.20 Watertight collars

4.20.1 Watertight collars are to be fitted, where stiffeners are continuous through watertight or oiltight boundaries, *see also* LR's *Guidance Notes for Structural Details*.

Table 2.4.5 Secondary member end connection welds

Connection	Weld area, A_w, in cm^2	Weld factor
(1) Stiffener welded direct to plating	$0{,}25A_s$ or 6,5 cm^2 whichever is the greater	0,34
(2) Bracketless connection of stiffeners or stiffener lapped to bracket or bracket lapped to stiffener:		
(a) in dry space	$1{,}2\sqrt{Z}$	0,27
(b) in tank	$1{,}4\sqrt{Z}$	0,34
(c) main frame to tank side bracket in $0{,}15L_R$ forward	as (a) or (b)	0,34
(3) Bracket welded to face of stiffener and bracket connection to plating	—	0,34
(4) Stiffener to plating for 0,1 x span at ends, or in way of the end bracket if that be greater	—	0,34

Symbols

A_s = cross section area of the stiffener, in cm^2

A_w = the area of the weld, in cm^2, and is calculated as total length of weld, in cm, x throat thickness, in cm

Z = the section modulus, in cm^3, of the stiffener on which the scantlings of the end bracket are based.

NOTE

For maximum and minimum weld fillet sizes, *see* Table 2.4.4.

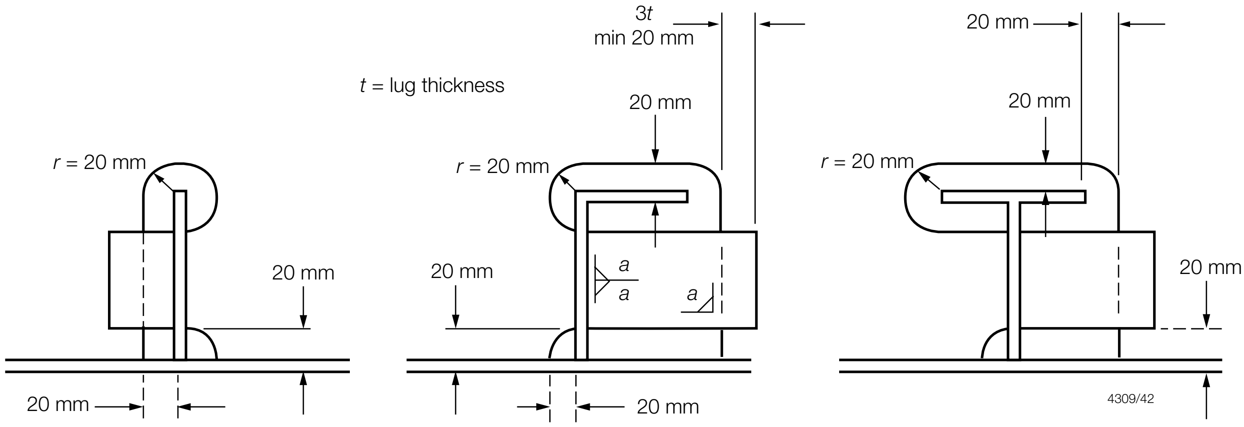


Fig. 2.4.3 Typical lug connections

4.21 Lug connections

4.21.1 The area of the weld connecting secondary stiffeners to primary structure in the bottoms of the hulls and cross-deck structure in areas subjected to impact pressures is to be not less than the shear area from the Rules. This area is to be obtained by fitting two lugs or by other equivalent arrangements. Some typical lug connections are shown in Fig. 2.4.3 and Fig. 3.1.7 in Chapter 3.

4.21.2 Lugs or tripping brackets are to be fitted where shell longitudinals are continuous through web frames in way of highly stressed areas of the side shell (e.g. in way of fenders, etc.).

4.21.3 Lugs or tripping brackets are also to be fitted where continuous secondary stiffeners are greater than half the depth of the primary stiffeners.

4.22 Insert plates

4.22.1 Where thick insert plates are butt welded to thin plates, the edge of the thick plate may require to be tapered. The slope of the taper is generally not to exceed one in three.

4.22.2 The corners of insert plates are to be suitably radiused.

4.23 Doubler plates

4.23.1 Doubler plates are to be avoided in areas where corrosion may be a problem and access for inspection and maintenance is limited.

4.23.2 Where doubler plates are fitted, they are to have well radiused corners and the perimeter is to be continuously welded. Large doubler plates are also to be suitably slot welded, the details of which are to be submitted for consideration.

4.24 Joint preparation

4.24.1 Welded joints are to be prepared in accordance with 3.11. Typical butt joints are shown in Tables 2.4.1 and 2.4.2, *see also* LR's *Guidance Notes for Structural Details*.

4.24.2 All other types of joint are to be prepared, aligned and adjusted in accordance with the established joint design. Excessive force is not to be used in fairing and closing the work. The surfaces of parts to be joined are to be accurate, clean, dry and free from blemishes, grease and other contaminants which might adversely affect the joint quality.

4.25 Construction tolerances

4.25.1 The minimum requirements for construction tolerances are to be in accordance with Pt 3, Ch 1,8.

4.26 Riveting of light structure

4.26.1 Where it is proposed to adopt riveted construction, full details of the rivets or similar fastenings, including mechanical test results, are to be indicated on the construction plans submitted for approval or a separate riveting schedule is to be submitted.

4.26.2 Samples may be required of typical riveted joints made by the Builder under representative construction conditions and tested to destruction in the presence of the Surveyor in shear, tension, compression or peel at LR's discretion.

4.26.3 Where riveting strength data sheets have been issued by a recognised Authority, the values quoted in these sheets will normally be accepted for design purposes.

4.26.4 Where two dissimilar metals are to be joined by riveting, precautions are to be taken to eliminate electrolytic corrosion to LR's satisfaction, and where practicable, the arrangements should be such as to enable the joint to be kept under observation at each survey without undue removal of lining and other items.

4.26.5 Where a sealing compound is used to obtain an airtight or watertight joint, details are to be submitted of its proposed use and of any tests made or experience gained in its use for similar applications.

4.26.6 Aluminium alloy rivets in accordance with Ch 8,2 of the Rules for Materials are to be used where practicable. However, in the case of composite structures, including steel and GRP, consideration will be given to the use of steel rivets. In such cases, the mating surfaces are to be coated with a sealing paint.

4.26.7 Sealing paints or compounds are not to be used with hot driven rivets.

4.27 Chemical bonding of structure

4.27.1 Where chemical bonding of aluminium alloy of any load-bearing structure is proposed, details of the materials and the processes to be used are to be submitted for approval. These details are to include test results of samples manufactured under LR survey under workshop conditions to verify the strength, ageing effects and moisture resistance.

4.27.2 The adhesive manufacturer's recommendations in respect of the specified jointing system, comprising preparation of the surfaces to be adhered, the adhesive, bonding and curing processes, are to be strictly followed as variation of any step can severely affect the performance of the joint.

4.27.3 Meticulous preparation is essential where the joint is to be made by chemical bonding. The method of producing bonded joints is to be documented so that the process is repeatable after the procedure has been properly established.

4.27.4 Bonded joints are suitable for carrying shear loads, but are not in general to be used in tension or where the load causes peeling or other forces tending to open the joint. Loads are to be carried over as large an area as possible.

4.27.5 Bonded joints are to be suitably supported after assembly for the period necessary to allow the optimum bond strength of the adhesive to be to be developed. Entrained air pockets are to be avoided.

4.27.6 The use of adhesives for main structural joints is not to be contemplated unless considerable testing has established its validity, including environmental testing and fatigue testing where considered necessary by LR.

4.28 Triaxial stress considerations

4.28.1 Particular care is to be taken to avoid triaxial stresses which may result from poor joint design. Detailed joint design is of particular importance in aluminium structures more so than many other materials. Some recommendations in this respect are contained in LR's *Guidance Notes for Structural Details*.

4.29 Butt straps

4.29.1 In general, the scantling derivation of welded structures are to be determined using the mechanical properties of the aluminium alloy in the welded condition in accordance with 2.4. However, where stiffeners are butt welded, special consideration will be given to the use of suitable butt straps on the flanges which sufficiently reinforce the area of the weld to allow the scantlings to be determined using the unwelded mechanical properties. The butt weld is to be completed and generally made flush with the flange of the stiffening member before the butt strap is fitted and the butt strap weld is to be continuous. Where this jointing method is proposed, the scantlings, arrangements and locations of all joints and butt straps are to be submitted. Additionally, LR may require mechanical tests to be carried out to demonstrate the effectiveness of such arrangements.

4.30 Extruded 'planking'

4.30.1 Joints between adjacent extruded aluminium alloy planking, and the attachment of the planking to the supporting structure is in general to be by means of continuous welding.

4.30.2 The planking is generally not to be included in the determination of the section properties for both section modulus and inertia. However, special consideration will be given to the inclusion of such materials on the basis of the efficiency of the connection to the supporting structure.

4.31 Aluminium/steel transition joints

4.31.1 Provision is made in this Section for explosion bonded composite aluminium/steel transition joints used for connecting aluminium structures to steel plating. Such joints are to be used in accordance with the manufacturer's requirements, *see also* Ch 8,4 of the Rules for Materials.

4.31.2 Transition joints are to be manufactured by an approved producer in accordance with an approved specification which is to include the maximum temperature allowable at the interface during welding.

4.31.3 The aluminium material is to comply with the requirements of Section 2 and the steel is to be of an appropriate grade complying with the requirements of Ch 3,2 of the Rules for Materials.

4.31.4 Alternative materials which comply with International, National or proprietary specifications may be accepted provided that they give equivalence to the requirements of 4.31.3 or are approved for a specific application.

4.31.5 Intermediate layers between the aluminium and steel may be used, in which case the material of any such layer is to be specified by the manufacturer and is to be recorded in the approval certificate. Any such intermediate layer is then to be used in all production transition joints.

4.31.6 Bimetallic joints where exposed to seawater or used internally within wet spaces are to be suitably protected to prevent galvanic corrosion.

4.32 Aluminium/wood connection

4.32.1 To minimise corrosion of aluminium when in contact with wood in a damp or marine environment the timber is to be primed and painted in accordance with good practice. Alternatively the surface of the aluminium in contact with the timber is to be coated with a substantial thickness of a suitable sealant.

4.32.2 Timbers such as western red cedar, oak and chestnut are not, unless well seasoned, to be directly in contact with aluminium.

4.32.3 Timber preservatives of the following types should be avoided: copper napthanate, copper-chrome-arsenate, borax-boric acid.

Section 1 General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull craft of aluminium construction as defined in Pt 1, Ch 2,2.

1.2 General

1.2.1 The formulae contained within this Chapter are to be used in conjunction with the design loadings from Part 5 to determine the Rule scantling requirements.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,3.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

k_a = alloy factor
= $125/\sigma_a$
l = stiffener overall length, in metres
l_e = effective span length, in metres, as defined in 1.19
p = design pressure, in kN/m^2, as given in Part 5
s = stiffener spacing, in mm
t_p = plating thickness, in mm
A_w = shear area of stiffener web, in cm^2
B = moulded breadth of craft, in metres, as defined in Pt 3, Ch 1,6
E = modulus of elasticity, in N/mm^2
I = moment of inertia, in cm^4
L_R = Rule length of craft, in metres, as defined in Pt 3, Ch 1,6
Z = section modulus of the stiffening member, in cm^3
β = panel aspect ratio correction factor as defined in 1.15
γ = convex curvature correction factor as defined in 1.14
σ_a = guaranteed minimum 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2, *see also* Ch 2,2.4.2

$$\tau_a = \frac{\sigma_a}{\sqrt{3}}$$

1.6 Rounding policy for Rule plating thickness

1.6.1 Where plating thicknesses as determined by the Rules require to be rounded then this is to be carried out to the nearest full or half millimetre, with thicknesses 0,75 and 0,25 being rounded up.

1.7 Dimensional tolerance

1.7.1 Dimensional tolerances for materials are to be in accordance with Chapter 8 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), or an acceptable National or International Standard.

1.7.2 The under thickness tolerance acceptable for classification is to be considered as the lower limit of a range of thickness tolerance which could be found in the normal production of a conventional rolling mill manufacturing material, on average, to the nominal thickness.

1.7.3 The Owners and Builders may agree in individual cases whether they wish to specify a more stringent under thickness tolerance than that given in 1.7.2.

1.7.4 The minus tolerance on sections (except for wide flats) is to be in accordance with a National or International Standard.

1.7.5 The thickness of plates and strip is to be measured at random locations whose distance from an edge is to be at least 25 mm. Local surface depressions resulting from imperfections and ground areas resulting from the elimination of defects may be disregarded provided that they are in accordance with the requirements of a National or International Standard.

1.7.6 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer/Builder. Occasional checking by the Surveyor does not absolve the manufacturer/Builder from the responsibility.

1.8 Material properties

1.8.1 The basic grade of aluminium alloy is taken as marine grade 5083-0 with the following mechanical properties:

	N/mm^2
0,2 per cent proof stress (minimum)	125
Tensile strength	260
Modulus of elasticity	69×10^3

1.8.2 Where other alloy grades with differing mechanical properties are to be used, due allowance is given in the determination of the Rule requirement for plating thickness, section modulus, inertia and cross-sectional area by use of the following correction factors:

(a) Plating thickness factor = $\sqrt{k_a}$

(b) Section modulus and cross section area factor = k_a where k_a is as defined in 1.5.1.

1.9 High strength sheet and plate

1.9.1 Particular attention is to be given to the welding procedures for the welding of high strength sheet and plate. The 0,2 per cent yield strength values in the welded condition will, in general, be significantly less than in the unwelded condition. These reduced values are to be used in the determination of the Rule scantlings.

1.10 High strength extrusions

1.10.1 The requirements of 1.9 are to be complied with. However, special consideration will be given to the use of un-welded strength properties for use in the determination of the Rule scantlings provided that suitable compensation is provided in way of welding on the face of the stiffener. This compensation can be provided by butt-straps or other acceptable arrangements, *see also* Ch 2,4.29.

1.10.2 The application of high strength extrusions is in general limited to superstructures, deckhouses, decks and bulkheads. Special consideration will be given to their use in other areas.

1.10.3 Butt welds and seams are to be carefully positioned clear of areas of high stress and where practicable are to be orientated parallel to the direction of the main stresses.

1.11 Effective width of attached plating

1.11.1 The effective geometric properties of rolled or built sections are to be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the actual plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

1.11.2 For stiffening members, the geometric properties of rolled or built sections are to be calculated in association with an effective area of attached load bearing plating of thickness t_p, in mm and a breadth b_e, in mm, b_e is as defined in 1.11.3 and 1.11.4.

1.11.3 The effective width of attached plating to secondary members b_e is to be taken as $2t_p\sqrt{E/\sigma_a}$ but not greater than s. σ_a is not to be taken as greater than 169 N/mm^2 for aluminium alloy. E, s and σ_a are as defined in 1.5.1.

1.11.4 The effective breadth of attached plating to primary support members (girders, transverses, webs, etc.) b_e is to be taken as bf, where b and f are as defined in Pt 3, Ch 2,3.2.1.

1.11.5 Where primary stiffening members support areas of plating of the extruded plank type, or the floating frame system is used, the effect of the plating attached to the secondary stiffening members is to be ignored when calculating the actual section modulus and inertia of the primary stiffening members, i.e. the full section modulus and inertia are to be provided by the primary stiffening member only, *see also* Ch 2,4.30.

1.12 Other materials

1.12.1 Special consideration will be given to the use of materials other than aluminium alloy. Details of the type of material, the specification to which it was manufactured and its mechanical properties are to be submitted for appraisal.

1.13 Fibre reinforced plastic (FRP)

1.13.1 The use of FRP in construction is to be in accordance with Part 8.

1.14 Convex curvature correction

1.14.1 The thickness of plating as determined by the Rules may be reduced where significant curvature exists between the supporting members. In such cases a plate curvature correction factor may be applied:

γ = plate curvature factor
= $1 - h/s$, and is not to be taken as less than 0,7

h = the distance, in mm, measured perpendicularly from the chord length s (i.e. spacing) to the highest point of the curved plating arc between the two supports

See Fig. 3.1.1.

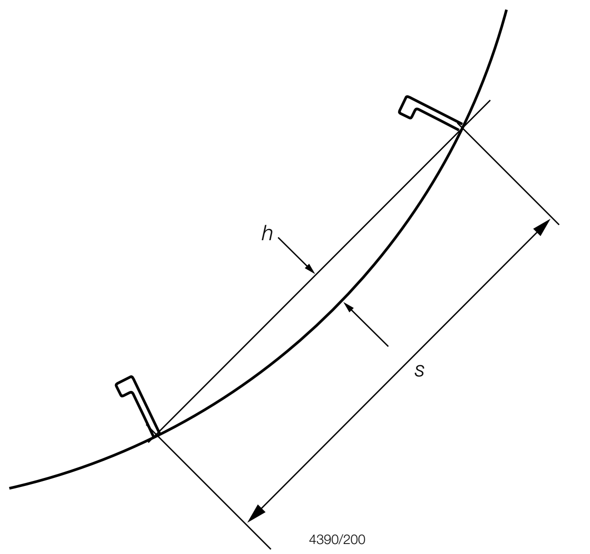


Fig. 3.1.1 Convex curvature

1.15 Aspect ratio correction

1.15.1 The thickness of plating as determined by the Rules may be reduced when the panel aspect ratio is taken into consideration. In such cases a panel aspect ratio correction factor may be applied:

β = aspect ratio correction factor
= $A_R (1 - 0{,}25 A_R)$ for $A_R \leq 2$
= 1 for $A_R > 2$

where

A_R = panel aspect ratio
= panel length/panel breadth.

1.16 Plating general

1.16.1 The requirements for the thickness of plating, t_p, is, in general, to be in accordance with the following:

$$t_p = 22{,}4 s \gamma \beta \sqrt{\frac{p}{f_\sigma \sigma_a}} \times 10^{-3} \text{ mm}$$

where

f_σ = limiting bending stress coefficient for the plating element under consideration is given in Table 7.3.1 in Chapter 7.

s, γ, β, p, σ_a are as defined in 1.5.1.

1.17 Stiffening general

1.17.1 The requirements for section modulus, inertia and web area of stiffening members are in general to be in accordance with the following:

(a) Section modulus:

$$Z = \Phi_Z \frac{p\, s\, l_e^2}{f_\sigma \sigma_a} \text{ cm}^3$$

where

Φ_Z = section modulus coefficient dependent on the loading model assumption taken from Table 3.1.1

f_σ = limiting bending stress coefficient for stiffening member given in Table 7.3.1 in Chapter 7.

p, s, l_e and σ_a are as defined in 1.5.

(b) Inertia:

$$I = \Phi_I f_\delta \frac{p\, s\, l_e^3}{E} \times 100 \text{ cm}^4$$

where

Φ_I = inertia coefficient dependent on the loading model assumption taken from Table 3.1.1

f_δ = limiting deflection coefficient for stiffener member given in Table 7.2.1 in Chapter 7.

p, s, l_e and E are as defined in 1.5.1.

(c) Web area:

$$A_w = \Phi_A \frac{p\, s\, l_e}{100 f_\tau \tau_a} \text{ cm}^2$$

where

Φ_A = web area coefficient dependent on the loading model assumption taken from Table 3.1.1

f_τ = limiting shear stress coefficient for stiffener member given in Table 7.3.1 in Chapter 7

p, s, l_e and τ_a are as defined in 1.5.1.

1.18 Geometric properties and proportions of stiffener sections

1.18.1 From structural stability and local buckling considerations, the proportions of stiffening members are, in general, to be in accordance with Table 3.1.2.

Table 3.1.1 Section modulus, inertia and web area coefficients

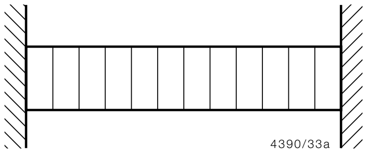
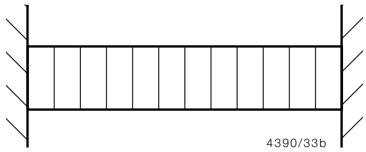
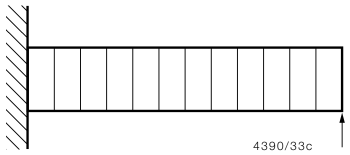
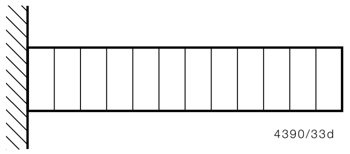
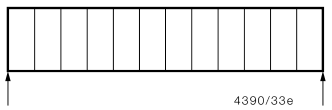
Load model	Position 1	Position 2	Position 3	Position	Web area coefficient Φ_A	Section modulus coefficient Φ_Z	Inertia coefficient Φ_I	Application
(a)				1 2 3	1/2 — 1/2	1/12 1/24 1/12	— 1/384 —	Primary and other members where the end fixity is considered encastre
(b)				1 2 3	1/2 — 1/2	1/10 1/10 1/10	— 1/288 —	Local, secondary and other members where the end fixity is considered to be partial
(c)				1 2 3	5/8 — 3/8	1/8 9/128 —	— 1/185 —	Various
(d)				1 2 3	1 — —	1/2 — —	— — 1/8	Various
(e)				1 2 3	1/2 — 1/2	— 1/8 —	— 5/384 —	Hatch covers, glazing and other members where the ends are simply supported

Table 3.1.2 Stiffener proportions

Type of stiffener	Requirement
(1) Flat bar	Minimum web thickness: $t_w = d_w/15$ ≥ 3 mm
(2) Rolled or built sections	(a) Minimum web thickness: $t_w = d_w/50$ ≥ 3 mm (b) Maximum unsupported face plate (or flange) width: $b_f = 16\ t_f$
Symbols	
t_w = web thickness of stiffener with unstiffened webs, in mm d_w = web depth of stiffener, in mm b_f = face plate (or flange) unsupported width, in mm t_f = face plate (or flange) thickness, in mm	

1.19 Determination of span point

1.19.1 The effective length of span, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined as follows:

(a) For rolled or built-up secondary stiffening members:
The span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member, is equal to the depth of the member, *see* Fig. 3.1.2. Where there is no end bracket, the span point is to be measured between primary member webs.

(b) For primary support members:
The span point is to be taken at a point distant, b_e from the end of the member, where

$$b_e = b_b\left(1 - \frac{d_w}{d_b}\right)$$

where b_e, b_b, d_w and d_B are as shown in Fig. 3.1.2.

1.19.2 Where the stiffener member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

1.19.3 Where the stiffening member is curved then the span is to be taken as the effective chord length between span points.

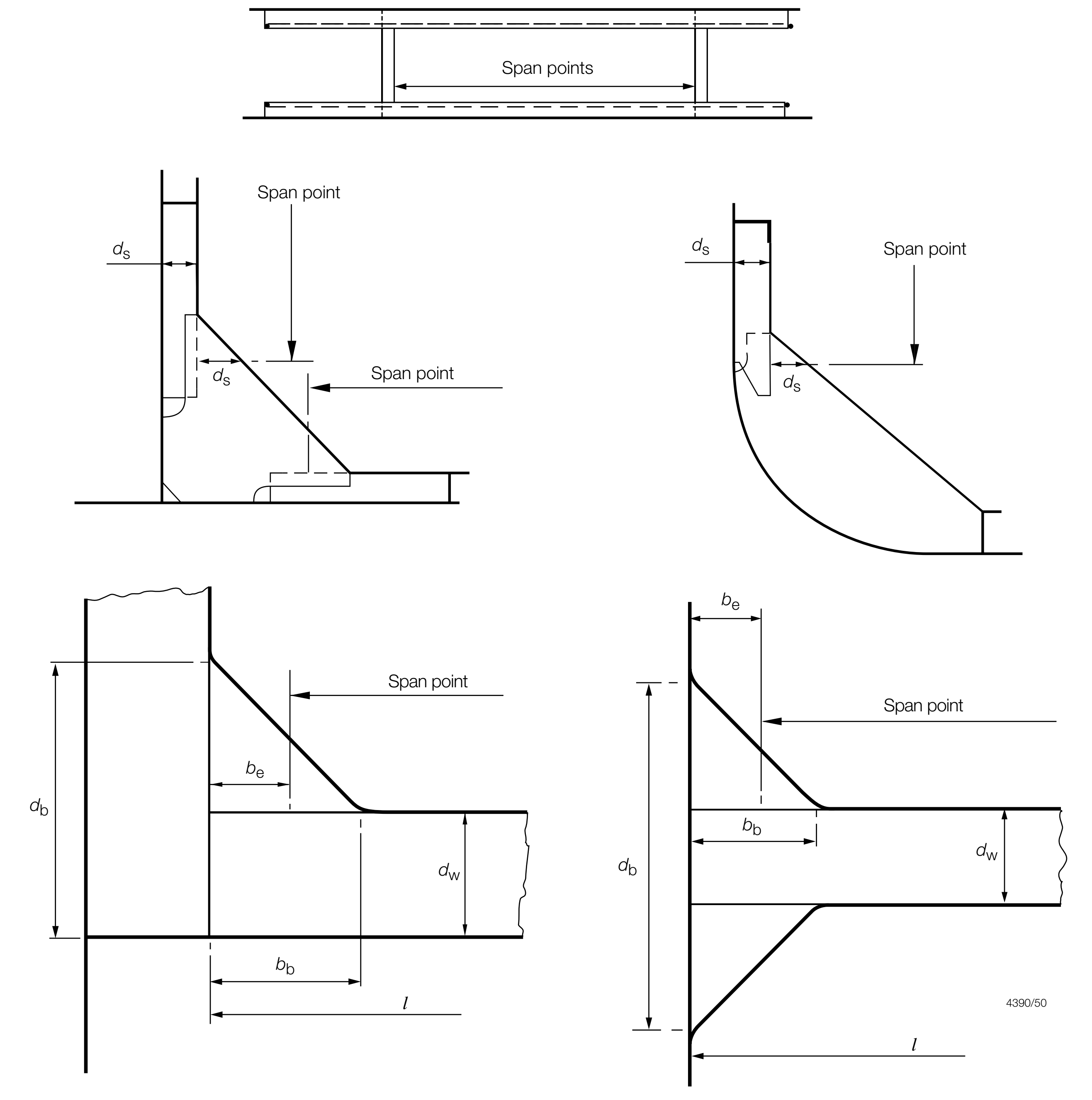


Fig. 3.1.2 Span points

1.19.4 Where there is a pronounced turn of bilge, chine or the structure is significantly pitched, the span may be measured as in Fig. 3.1.2.

1.19.5 It is assumed that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.

1.20 Secondary member end connections

1.20.1 Secondary members, that is longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are to be effectively continuous and are to be suitably bracketed at their end connections. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered, *see also* Ch 2,4.16 and Table 2.4.5 in Chapter 2.

1.20.2 Where bracketed end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

1.20.3 The scantlings of secondary member end connections are to be in accordance with 1.21.

1.21 Scantlings of end brackets

1.21.1 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the scantlings of the end brackets are to be such that their section modulus and effective cross-sectional area are not less than those of the member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

1.21.2 In other cases the scantlings of the bracket are to be based on the modulus as follows:

(a) Bracket connecting stiffener to primary member – modulus of the stiffener.

(b) Bracket at the head of a main transverse frame where frame terminates – modulus of the frame.

(c) Brackets connecting lower deck beams or longitudinals to the main frame in the forward $0{,}5L_R$ – modulus of the frame.

(d) Elsewhere – the lesser modulus of the members being connected by the bracket.

1.21.3 The web thickness and face flat area of end brackets are not in general to be less than those of the connecting stiffeners. Additionally, the stiffener proportion requirements of 1.18 are to be satisfied.

1.21.4 Typical arrangements of stiffener end brackets are shown diagrammatically in Fig. 3.1.3.

1.21.5 The lengths, *a* and *b* of the arms are to be measured from the plating to the toe of the bracket and are to be such that:

(a) $a + b \geq 2{,}0 l_b$

(b) $a \geq 0{,}8 l_b$

(c) $b \geq 0{,}8 l_b$

where *a* and *b* are the actual lengths of the two arms of the bracket, in mm, measured from the plating to the toe of the bracket.

$$l_b = 90\left(2\sqrt{\frac{Z}{14 + \sqrt{Z}}} - 1\right) \text{ mm}$$

Z = the section modulus of the secondary member, in cm^3

In no case is l_b to be taken as less than twice the web depth of the stiffener on which the bracket scantlings are to be based.

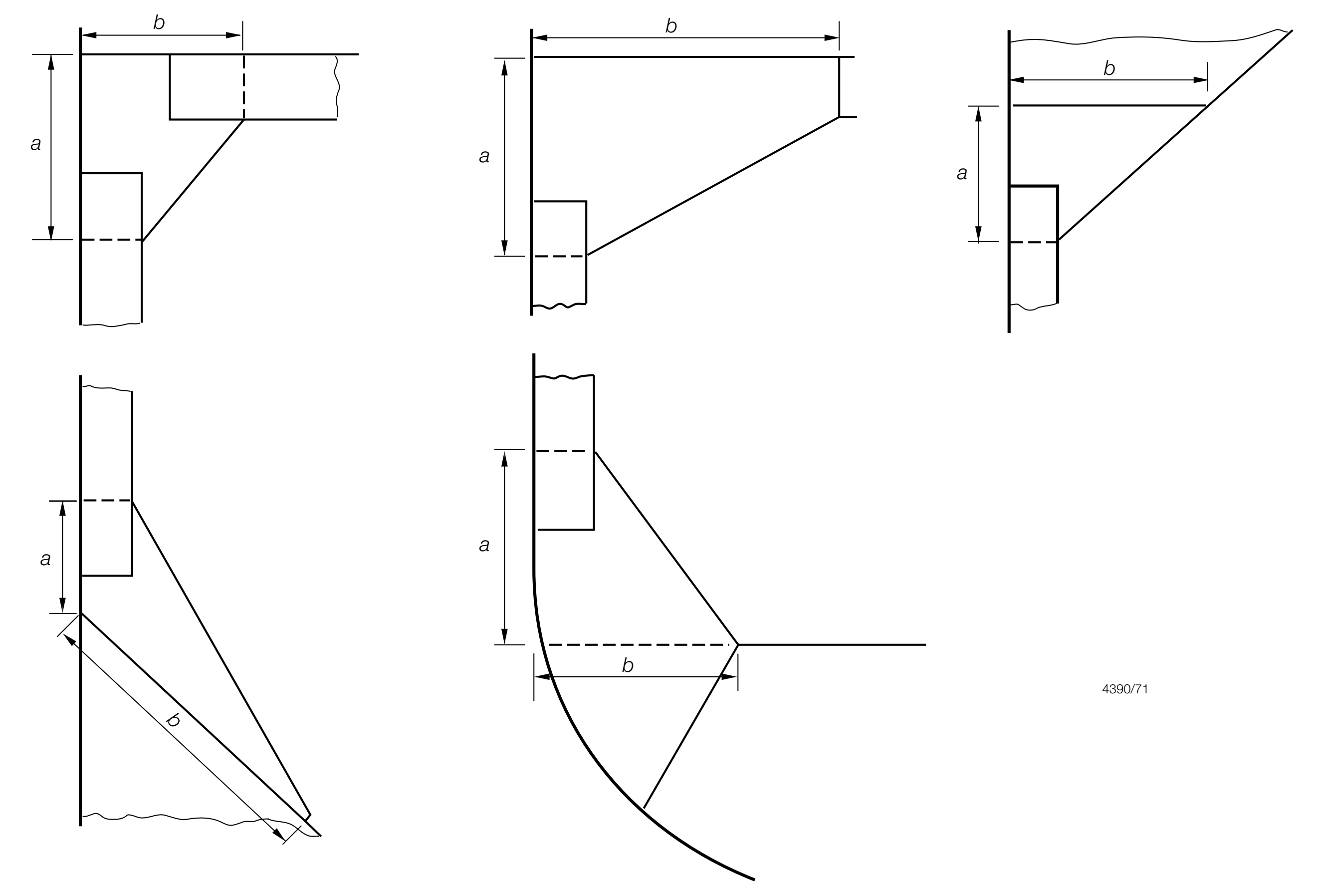


Fig. 3.1.3 Stiffener end brackets

1.21.6 The free edge of the bracket is to be stiffened where any of the following apply:

(a) The section modulus, Z, exceeds 500 cm^3.

(b) The length of free edge exceeds 40 times the bracket thickness.

(c) The bracket is fitted at the lower end of main transverse side framing.

1.21.7 Where a face flat is fitted, its breadth, b_f, is to be not less than:

$$b_f = 30\left(1 + \frac{Z}{1000}\right) \text{ mm}$$

but not less than 40 mm.

1.21.8 Where the edge is stiffened by a welded face flat, the cross-sectional area of the face flat is to be not less than:

(a) $0{,}017 k_a b_f T_B$ cm^2 for offset edge stiffening.

(b) $0{,}014 k_a b_f T_B$ cm^2 for symmetrically placed stiffening.

b_f = breadth of face flat, in mm

T_B = the thickness of the bracket, in mm

k_a is as defined in 1.5.1.

1.21.9 Where the stiffening member is lapped onto the bracket, the length of overlap is to be adequate to provide for the required area of welding. In general, the length of overlap is not to be less than $10\sqrt{Z}$, or the depth of stiffener, whichever is the greater.

1.21.10 Where the free edge of the bracket is hollowed out, it is to be stiffened or increased in size to ensure that the modulus of the bracket through the throat is not less than that of the required straight edged bracket.

1.21.11 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the actual modulus reduced to less than that of the stiffener with associated plating.

1.21.12 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.22 Primary member end connections

1.22.1 The requirements for section modulus and inertia (if applicable) of primary members are given in the appropriate Chapter. The scantling requirements for primary member end connections in dry spaces and in tanks of all craft types are generally to comply with the requirements of 1.21, taking Z as the section modulus of the primary member.

1.22.2 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

1.22.3 The members are to have adequate lateral stability and web stiffening and the structure is to be arranged to minimise hard spots and other sources of stress concentration. Openings are to have well rounded corners and smooth edges and are to be located having regard to the stress distribution and buckling strength of the panel.

1.22.4 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

1.22.5 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended beyond the point of support and thereafter tapered and/or scarfed into the adjacent structure over a distance generally not less than two frame spaces.

1.22.6 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening may be required.

1.22.7 The thickness of the bracket is to be not less than that of the primary member web. The free edge of the bracket is to be stiffened.

1.22.8 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

1.22.9 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Proposals to fit brackets of reduced scantlings, or alternative arrangements, will be considered.

1.22.10 Connections between primary members forming a ring system are to minimise stress concentrations at the junctions. Integral brackets are generally to be radiused or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

1.23 Tank boundary penetrations

1.23.1 Where structural members pass through the boundary of a tank, and leakage into the adjacent space could be hazardous or undesirable, full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively a small scallop of suitable shape may be cut in the member close to the boundary outside the compartment, and carefully welded all round.

1.24 Web stability

1.24.1 Primary members of asymmetrical section are to be supported by tripping brackets at alternate secondary members. If the section is symmetrical, the tripping brackets may be four spaces apart.

1.24.2 Tripping brackets are in general required to be fitted at the toes of end brackets and in way of heavy or concentrated loads such as the heels of pillars. *See also* LR's *Guidance Notes for Structural Details*.

1.25 Openings in the web

1.25.1 Where openings are cut in the web, the depth of opening is not to exceed 50 per cent of the web depth, and the opening is to be so located that the edges are not less than 25 per cent of the web depth from the face plate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered.

1.25.2 Openings are to have smooth edges and well rounded corners.

1.26 Continuity and alignment

1.26.1 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

1.26.2 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment.

1.26.3 Pillars and pillar bulkheads are to be fitted in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

1.26.4 Continuity is to be maintained where primary members intersect and where the members are of the same depth, a suitable gusset plate is to be fitted, *see* Fig. 3.1.4.

1.26.5 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

1.26.6 The toes of brackets, etc., are not to land on unstiffened panels of plating. Special care is to be taken to avoid notch effects at the toes of brackets, by making the toe concave or otherwise tapering it off, *see also* LR's *Guidance Notes for Structural Details*.

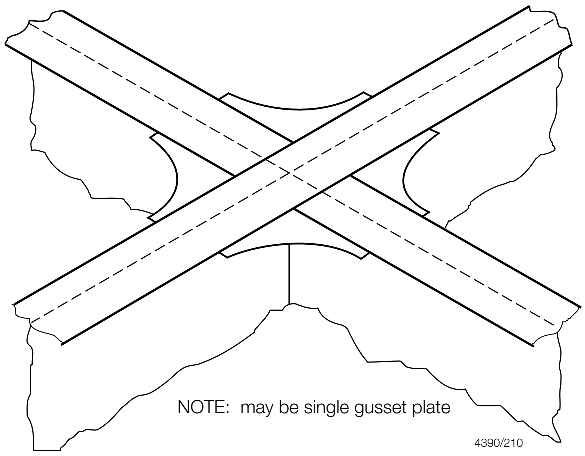


Fig. 3.1.4 Primary member intersection

1.26.7 Particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face plates which are welded onto the edge of primary member brackets are to be carried well around the radiused part of the bracket toe and are to incorporate a taper not exceeding one in three. Where sniped face plates are welded adjacent to the edge of primary member brackets, adequate cross sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area measured perpendicular to the face plate, is to be not less than 60 per cent of the full cross-sectional area of the face plate, *see* Fig. 3.1.5.

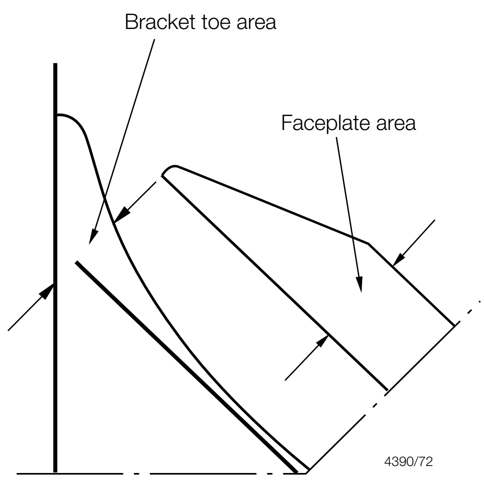


Fig. 3.1.5 Bracket toe construction

1.27 Arrangement with offset stiffener

1.27.1 Where the stiffeners of the double bottom floors and transverse bulkheads are unconnected to the secondary members and offset from them, *see* Fig. 3.1.6, the collar arrangement for the secondary members are to satisfy the requirements of 1.28. In addition, the fillet welds attaching the lugs to the secondary members are to be based on a weld factor of 0,44 for the throat thickness. To facilitate access for welding the offset stiffeners are to be located 50 mm from the slot edge furthest from the web of the secondary member. The ends of the offset stiffeners are to be suitably tapered and softened.

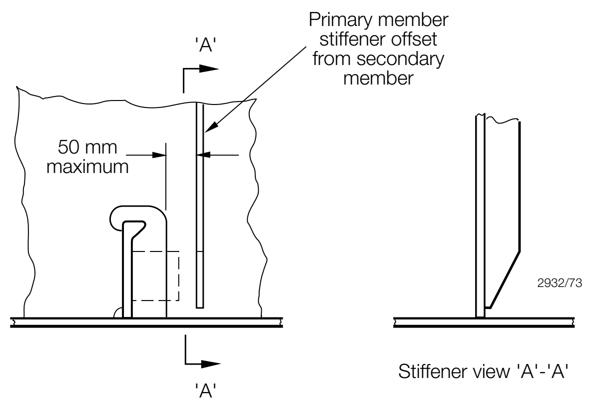


Fig. 3.1.6 Arrangement with offset stiffener

1.27.2 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.28 Arrangements at intersection of continuous secondary and primary members

1.28.1 Cut-outs for the passage of secondary members through the webs of primary members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating. The critical shear buckling stress of the panel in which the cut-out is made is to be investigated. Cut-outs for longitudinals will be required to have double lugs in areas of high stress.

1.28.2 The breadth of cut-outs is to be as small as practicable, with the top edge suitably radiused. Cut-outs are to have smooth edges, and the corner radii are to be as large as practicable, with a minimum of 20 per cent of the breadth of the cut-out or 25 mm, whichever is the greater. It is recommended that the web plate connection to the hull envelope, or bulkhead, end in a smooth tapered 'soft toe'. Recommended shapes of cut-out are shown in Fig. 3.1.7, but consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration, *see also* LR's *Guidance Notes for Structural Details*.

1.28.3 Consideration is to be given to the provision of adequate drainage and unimpeded flow of air and water when designing the cut-outs and connection details.

1.28.4 Asymmetrical secondary members are to be connected on the heel side to the primary member web plate. Additional connection by lugs on the opposite side may be required.

1.28.5 Symmetrical secondary members are to be connected by lugs on one or both sides, as necessary.

1.28.6 Where the primary member stiffener is connected to the secondary member it is to be aligned with the web of the secondary member, except where the face plate of the latter is offset and abutted to the web, in which case the stiffener connection is to be lapped.

1.28.7 Fabricated longitudinals having the face plate welded to the underside of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where it is proposed to fit such sections, a symmetrical arrangement of connection to transverse members is to be incorporated. This can be achieved by fitting backing structure on the opposite side of the transverse web or bulkhead.

1.28.8 Where a bracket is fitted to the primary member web plate in addition to a connected stiffener it is to be arranged on the opposite side to, and in alignment with the stiffener. The arm length of the bracket is to be not less than the depth of the stiffener, and its cross-sectional area through the throat of the bracket is to be included in the calculation of the area of the primary web stiffener in way of the connection.

1.28.9 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.29 Openings

1.29.1 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or in floors and double bottom girders close to their span ends, or below the heels of pillars, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

1.29.2 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

1.29.3 Air and drain holes, notches and scallops are to be kept at least 200 mm clear of the toes of end brackets and other areas of high stress. Openings are to be well rounded with smooth edges. Closely spaced scallops are not permitted. Widely spaced air or drain holes may be accepted, provided that they are of elliptical shape, or equivalent, to minimise stress concentration and are, in general, cut clear of the weld connection.

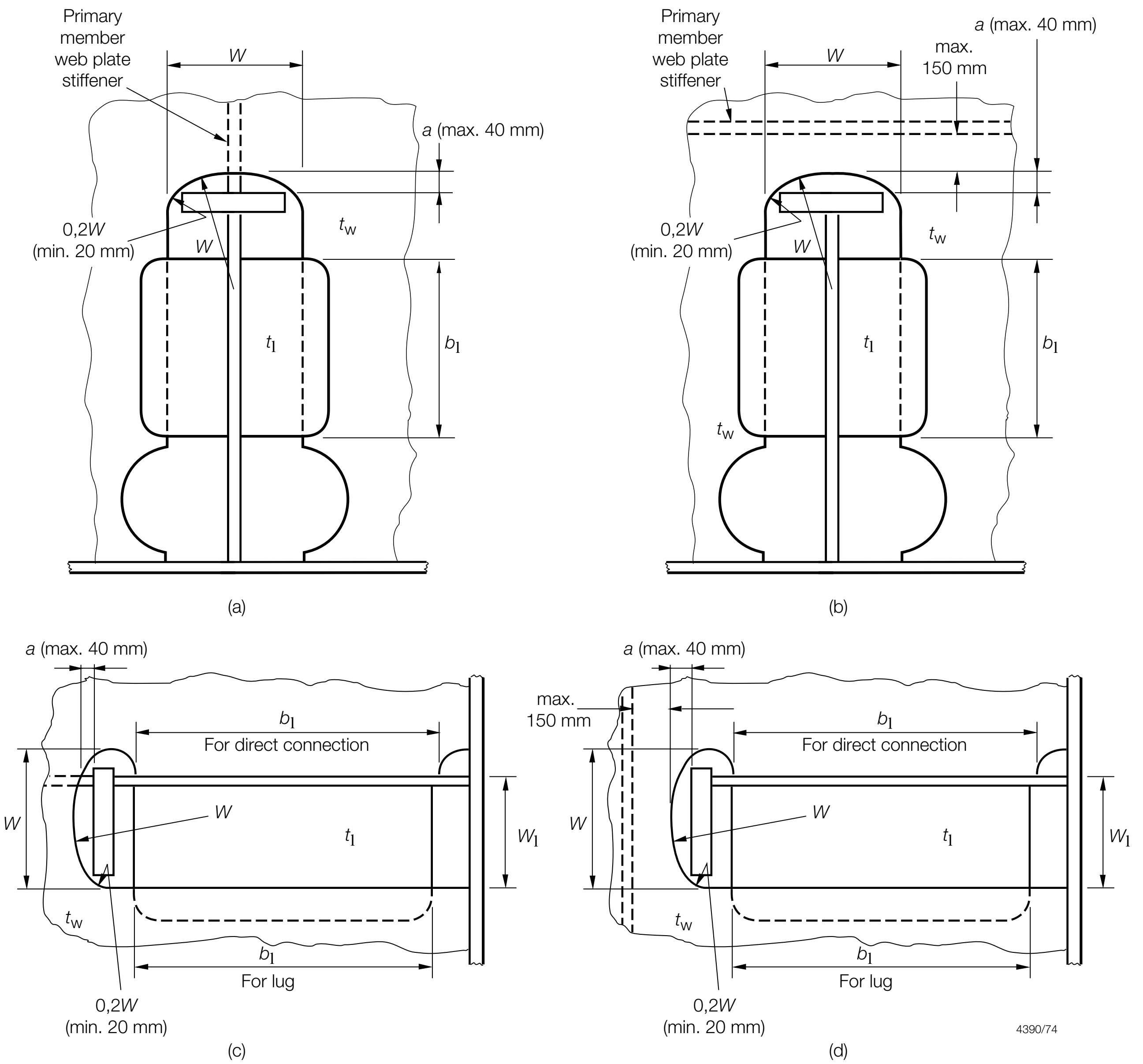


Fig. 3.1.7 Cut-outs and connections

1.30 Fittings and attachments, general

1.30.1 The quality of welding and general workmanship of fittings and attachments as given in 1.31 and 1.32 are to be in accordance with Ch 2,3.18.

1.31 Bilge keels and ground bars

1.31.1 It is recommended that bilge keels are not to be fitted in the forward $0{,}3L_R$ region on ships intended to navigate in ice conditions.

1.31.2 Bilge keels are to be attached to a continuous ground bar as shown in Fig. 3.1.8. Butt welds in shell plating, ground bar and bilge keels are to be staggered.

1.31.3 The thickness of the ground bar is to be not less than the thickness of the bottom shell or 8 mm, whichever is the greater, but need not be taken as greater than 15 mm.

1.31.4 The material class, grade and quality of the ground bar are to be similar to those of the adjacent shell plating.

1.31.5 The ground bar is to be connected to the shell with a continuous fillet weld and the bilge keel to the ground bar with a light continuous fillet weld.

1.31.6 Direct connection between ground bar butt welds and shell plating, and between bilge keel butt welds and ground bar is to be avoided.

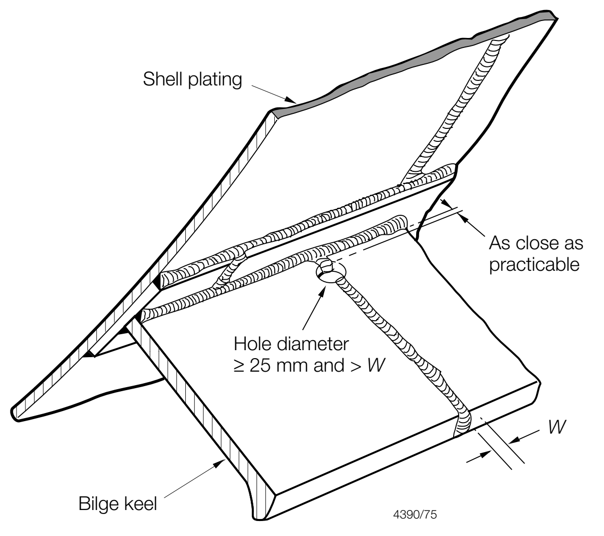


Fig. 3.1.8 Bilge keel construction

1.31.7 The end details of bilge keels and intermittent bilge keels, where adopted, are to be as shown in Fig. 3.1.9.

1.31.8 The ground bar and bilge keel ends are to be tapered or rounded. Where the ends are tapered, the tapers are to be gradual with ratios of at least 3:1, *see* Figs. 3.1.9(a) and (b). Where the ends are rounded, details are to be as shown in Fig. 3.1.9(c). Cut-outs on the bilge keel web within zone 'A' (*see* Fig. 3.1.9(b)) are not permitted.

1.31.9 The end of the bilge keel web is to be between 50 mm and 100 mm from the end of the ground bar, *see* Fig. 3.1.9(a).

1.31.10 An internal transverse support is to be positioned as close as possible to halfway between the end of the bilge keel web and the end of the ground bar, *see* Fig. 3.1.9(b).

1.31.11 Where an internal longitudinal stiffener is fitted in line with the bilge keel web, the longitudinal stiffener is to extend to at least the nearest transverse member outside zone 'A', *see* Fig. 3.1.9(b). In this case, the requirement of 1.31.10 does not apply.

1.31.12 For craft over 65 m in length, L_R, holes are to be drilled in the bilge keel butt welds. The size and position of these holes are to be as illustrated in Fig. 3.1.8. Where the butt weld has been subject to non-destructive examination the stop hole may be omitted.

1.31.13 Bilge keels of a different design from that shown in Fig. 3.1.8 and Fig. 3.1.9 will be specially considered.

1.31.14 Within zone 'B' (*see* Fig. 3.1.9(a)), welds at the ends of the ground bar and the bilge plating, and at the ends of the bilge keel web and ground bar, are to have weld factors of 0,44 and 0,34 respectively. These welds are to be ground and to blend smoothly with the base materials.

1.31.15 A plan of the bilge keels is to be submitted for approval of material grades, welded connections and detail design.

1.32 Other fittings and attachments

1.32.1 Gutterway bars at the upper deck are to be so arranged that the effect of main hull stresses on them is minimised.

1.32.2 Minor attachments, such as pipe clips, staging lugs and supports, are generally to be kept clear of toes of end brackets, corners of openings and similar areas of high stress. Where connected to asymmetrical stiffeners, the attachments may be in line with the web providing the fillet weld leg length is clear of the offset face plate or flange edge. Where this cannot be achieved the attachments are to be connected to the web, and in the case of flanged stiffeners they are to be kept at least 25 mm clear of the flange edge. On symmetrical stiffeners, they may be connected to the web or to the centre-line of the face plate in line with the web.

1.32.3 Where necessary in the construction of the craft, lifting lugs may be welded to the hull plating but they are not to be slotted through. Where they are subsequently removed, this is to be carried out by mechanical cutting close to the plate surface, and the remaining material and welding ground off. After removal the area is to be carefully examined to ensure freedom from cracks or other defects in the plate surface.

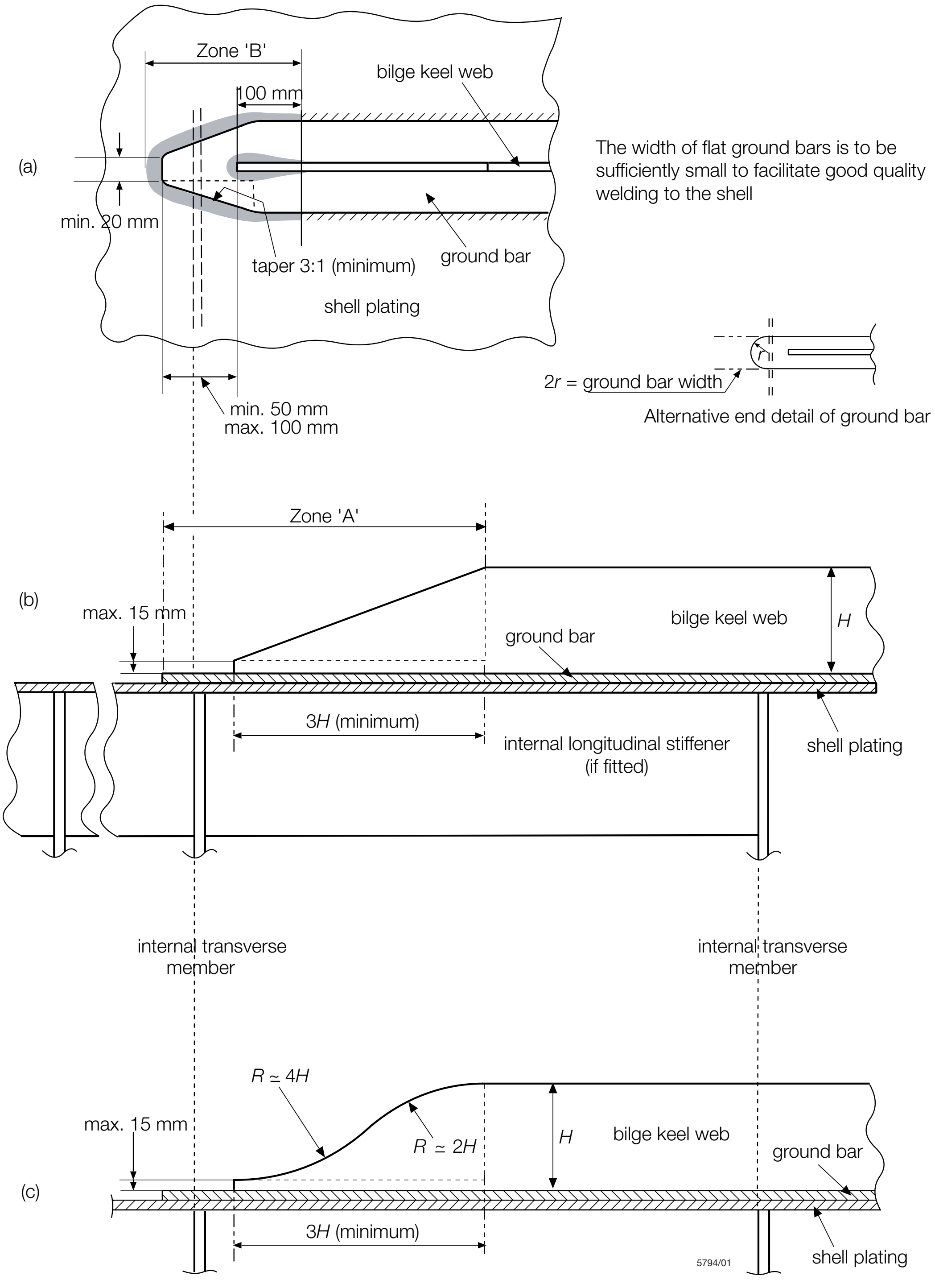


Fig. 3.1.9 Bilge keel end design

■ *Section 2* Minimum thickness requirements

2.1 General

2.1.1 The thickness of plating and stiffeners determined from the Rule scantling requirements is in no case to be less than that given in Table 3.2.1 for the craft type.

2.1.2 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy the global strength requirements detailed in Chapter 6.

2.2 Corrosion margin

2.2.1 The minimum thicknesses given in Table 3.2.1 are based on the assumption that there is negligible loss in strength by corrosion. Where this is not the case the minimum thickness will be specially considered.

Table 3.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Mono-hull	Hydrofoil	Rigid inflatable boat (RIB)
Shell envelope			
Bottom shell plating	$\omega\sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\,\omega$
Side shell plating	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$
Single bottom structure			
Centre girder web	$\omega\sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\,\omega$	$\omega\sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\,\omega$	$\omega\sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\,\omega$
Floor webs	$\omega\sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\,\omega$
Side girder webs	$\omega\sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\,\omega$
Double bottom structure Centre girder			
(1) Within $0{,}4L_R$ amidships	$\omega\sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\,\omega$	$\omega\sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\,\omega$	$\omega\sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\,\omega$
(2) Outside $0{,}4L_R$ amidships	$\omega\sqrt{k_m}\,(0{,}95\sqrt{L_R} + 1{,}4) \geq 5{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}95\sqrt{L_R} + 1{,}4) \geq 5{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}95\sqrt{L_R} + 1{,}4) \geq 5{,}0\,\omega$
Floors and side girders	$\omega\sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\,\omega$
Inner bottom plating	$\omega\sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}3) \geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}3) \geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}3) \geq 3{,}5\,\omega$
Bulkheads			
Watertight bulkhead plating	$\omega\sqrt{k_m}\,(0{,}43\sqrt{L_R} + 1{,}2) \geq 3{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}43\sqrt{L_R} + 1{,}2) \geq 3{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}43\sqrt{L_R} + 1{,}2) \geq 3{,}0\,\omega$
Deep tank bulkhead plating	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$
Deck plating and stiffeners			
Strength/Main deck plating	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$
Lower deck/Inside deckhouse	$\omega\sqrt{k_m}\,(0{,}3\sqrt{L_R} + 1{,}3) \geq 3{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}3\sqrt{L_R} + 1{,}3) \geq 3{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}3\sqrt{L_R} + 1{,}3) \geq 3{,}0\,\omega$
Superstructures and deckhouses			
Superstructure side plating	$\omega\sqrt{k_m}\,(0{,}4\sqrt{L_R} + 1{,}1) \geq 3{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}4\sqrt{L_R} + 1{,}1) \geq 3{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}4\sqrt{L_R} + 1{,}1) \geq 3{,}0\,\omega$
Deckhouse front 1st tier	$\omega\sqrt{k_m}\,(0{,}62\sqrt{L_R} + 1{,}8) \geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}62\sqrt{L_R} + 1{,}8) \geq 3{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}62\sqrt{L_R} + 1{,}8) \geq 3{,}5\,\omega$
Deckhouse front upper tiers	$\omega\sqrt{k_m}\,(0{,}55\sqrt{L_R} + 1{,}5) \geq 3{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}55\sqrt{L_R} + 1{,}5) \geq 3{,}0\,\omega$	$\omega\sqrt{k_m}\,(0{,}55\sqrt{L_R} + 1{,}5) \geq 3{,}0\,\omega$
Deckhouse aft	$\omega\sqrt{k_m}\,(0{,}25\sqrt{L_R} + 0{,}7) \geq 2{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}25\sqrt{L_R} + 0{,}7) \geq 2{,}5\,\omega$	$\omega\sqrt{k_m}\,(0{,}25\sqrt{L_R} + 0{,}7) \geq 2{,}5\,\omega$
Pillars			
Wall thickness of tubular pillars	$\omega\sqrt{k_m}\,0{,}07d_p$	$\omega\sqrt{k_m}\,0{,}07d_p$	$\omega\sqrt{k_m}\,0{,}07d_p$
Wall thickness of rectangular pillars	$\omega\sqrt{k_m}\,0{,}07b_p$	$\omega\sqrt{k_m}\,0{,}07b_p$	$\omega\sqrt{k_m}\,0{,}07b_p$

Symbols

ω = service type correction factor as determined from Table 3.2.2
k_m = $385/(\sigma_A + \sigma_u)$
σ_A = specified minimum yield stress or 0,2% proof stress of the alloy in unwelded condition, in N/mm^2
σ_u = specified minimum ultimate tensile strength of the alloy in unwelded condition, in N/mm^2
b_p = minimum breadth of cross section of hollow rectangle pillar, in mm
d_p = outside diameter of tubular pillar, in mm
L_R is as defined in 1.5.1.

Table 3.2.2 Service type correction factors (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,0
Patrol	1,0
Pilot	1,1
Yacht	1,0
Workboat MFV	1,2

2.3 Impact considerations

2.3.1 Due consideration is to be given to the scantlings of all structure which may be subject to local impact loadings. Impact testing may be required to be carried out at the discretion of LR to demonstrate the suitability of the proposed scantlings for a particular application.

2.4 Sheathing

2.4.1 Areas of shell and deck which are subject to additional wear by abrasion e.g. passenger routes, working areas of fishing craft, forefoot region etc, are to suitably protected by local reinforcement or sheathing. This sheathing may be of timber, rubber, steel, additional layers of reinforcement, etc., as appropriate. Details of such sheathing and the method of attachment are to be submitted for consideration.

2.4.2 The attachment of sheathing by mechanical means such as bolting or other methods is not to impair the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable. The design arrangements in way of any through bolting are to be such that damage to the sheathing will not impair the watertight integrity of the hull.

2.5 Operation in ice

2.5.1 The minimum plating thickness of craft intended for operation in ice conditions is to comply with Ch 5,7.

■ *Section 3*
Shell envelope plating

3.1 General

3.1.1 The requirements of this Section are applicable to longitudinally and transversely framed shell envelopes.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in Section 2.

3.2 Plate keel

3.2.1 The breadth, b_k, and thickness, t_k, of the plate keel are not to be taken as less than:

$$b_k = 7{,}0L_R + 340 \text{ mm}$$

$$t_k = 1{,}85\sqrt{k_a}\, L_R^{0{,}45} \text{ mm}$$

where L_R and k_a are as defined in 1.5.1.

3.2.2 In no case is the thickness of the plate keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of the plate keel are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by 3.3.1 for the stem.

3.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

3.2.5 For bar keels, *see* 5.2.2.

3.3 Plate stem

3.3.1 The thickness of plate stems, t_s, is not to be taken as less than:

$$t_s = \sqrt{k_a}\,(0{,}14L_R + 4) \text{ mm}$$

L_R and k_a are as defined in 1.5.1.

3.3.2 In no case is the thickness of the plate stem to be taken as less than the thickness of the adjacent shell plating.

3.3.3 Plate stems are to be supported by horizontal diaphragms, and where the stem radius is large, a centreline stiffener or web may be required. Where this is impracticable due to fabrication access considerations, alternative supporting arrangements will be specially considered

3.3.4 For large or novel craft the scantlings of the stem will be specially considered.

3.3.5 The breadth of plate stems is to be not less than the width of keel as required by 3.2.1.

3.4 Bottom shell plating

3.4.1 The thickness of the bottom shell plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types the minimum thickness requirement for bottom shell plating as, detailed in Section 2, is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater. *See* Fig. 3.3.1.

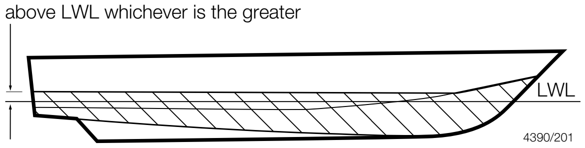


Fig. 3.3.1 Extent of bottom shell

3.5 Side shell plating

3.5.1 The thickness of the side shell plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.6 Sheerstrake

3.6.1 The sheerstrake is generally to be taken as the side shell, locally reinforced in way of deck/hull connection and fender attachment. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service.

3.6.2 The fendering arrangements for all craft types are the responsibility of the designers/Builders and are outside the scope of classification.

3.6.3 Where the pressure or impact loadings that a particular type of craft will experience in service are considered by the Builder, or subsequent Owner, to be not covered by or be greater than those indicated in Part 5 of the Rules, details of the loadings together with the calculations of how these will be satisfactorily distributed into the craft's structure, are to be submitted for consideration with the relevant construction plans.

3.6.4 The arrangements indicated in 3.6.5, 3.6.6, 4.18.2 and 4.18.3 for pilot and fishing craft are for the guidance of the Builder and subsequent Owners/operators of the craft. Where the intended service for either of these types of craft, or other types of craft which may be subject to loadings resulting from contact with other craft, jetties or similar loading or boarding facilities, is such that the loadings are greater than those that can be satisfactorily distributed into the craft's structure by the arrangements indicated, then the strengthening arrangements are to be increased accordingly.

3.6.5 For pilot craft which may be subject to repeated impact loadings from contact with other craft etc., the sheerstrake plating is to be increased locally by not less than 50 per cent of the side shell thickness. The increased thickness is to extend from the bow aft over a distance of $0,33L_R$ or 500 mm aft of the point which the deckline reaches its greatest breadth whichever is the greater and forward of the quarter and over the transom for a distance of $0,075L_R$ or 1,0 m, whichever is the greater. It is in general to extend from the deck edge to below the first longitudinal stiffener, or a vertical distance equivalent to 1/3 the freeboard height whichever is the greater. The additional thickness is then to be tapered out to the side shell thickness in accordance with the Rules.

3.6.6 Fishing craft are in general to have their shell plating scantling as required to satisfy the Rule loadings, increased by 20 per cent. Additionally the side shell is not to be taken less than as bottom shell thickness, and where there are gallows, gantries, nets, or lines etc. the plating in way is to be further increased locally and/or suitably protected by sheathing or other means.

3.6.7 Individual consideration will be given to lesser scantlings than those required by 3.6.3. for fishing craft used for pleasure, light duties, etc. Details of the service are to be submitted.

3.6.8 Where a rounded sheerstrake is adopted the radius, in general, is to be not less than 15 times the thickness.

3.6.9 The sheerstrake thickness is to be increased by 20 per cent at the ends of a bridge superstructure extending out to the craft's side. In the case of a bridge superstructure exceeding $0,15L_R$, the side plating at the ends of the superstructure is also to be increased by 25 per cent and tapered gradually into the upper deck sheerstrake.

3.6.10 In general, compensation will not be required for openings in the sheerstrake which are clear of the gunwale or deck openings and whose depth does not exceed 20 per cent of the depth of the sheerstrake. Openings are not to be cut in a rounded gunwale.

3.7 Chines

3.7.1 The chine plate thickness is to be equivalent to the bottom shell thickness required to satisfy the Rule pressure loading, increased by 20 per cent, or 6 mm, whichever is the greater.

3.7.2 Where tube is used in chine construction, the minimum wall thickness is to be not less than the thickness of the bottom shell plating increased by 20 per cent.

3.7.3 Full penetration welding of shell plating in way of chines is always to be maintained.

3.7.4 Chine details are to be such that the continuity of structural strength across the panel is maintained. Details of chines are to be submitted for consideration. *See also* LR's *Guidance Notes for Structural Details*.

3.8 Skegs

3.8.1 The thickness of the skeg plating is to be not less than the thickness of the adjacent bottom shell and additionally is to satisfy the requirements for sole pieces given in Ch 3,3 of the Rules for Materials.

3.9 Transom

3.9.1 The thickness of the stern or transom is to be not less than that required for the side or bottom shell as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.10 Fin and tuck

3.10.1 The thickness of the plating is to be increased locally in way of the fin and tuck areas of yachts which have either internal fixed ballast or external attached ballast keels.

3.10.2 The plating thickness is to be not less than 1,25 times the thickness of the adjacent shell plating but need not be greater than the plate keel thickness as required by 3.2.

3.11 Shell openings

3.11.1 Sea-inlets, or other openings, are to have well rounded corners and, so far as is practicable, are to be kept clear of the bilge radius, chine or radiused sheerstrake. Arrangements are to be made to maintain the strength in way of the openings.

3.11.2 Openings on or near the bilge radius may be accepted provided that they are of elliptical shape, or equivalent, to minimize stress concentrations and are, in general, to be cut clear of weld connections.

3.12 Sea inlet boxes

3.12.1 The thickness of the sea inlet box plating is to be 1 mm thicker than the adjacent shell plating, or 8 mm, whichever is the greater.

3.13 Local reinforcement/insert plates

3.13.1 The thickness of the shell envelope plating determined in accordance with 3.4 and 3.5 is to be increased locally, by generally not less than 50 per cent in way of stern-frame, propeller brackets, rudder horn, stabilizers, hawse pipes and anchor recess. Details of such reinforcement are to be submitted for approval.

3.13.2 Insert plates are to extend outside the line of adjacent supporting structure and then be tapered over a distance of not less than three times the difference in thickness, *see also* Ch 2,4.22.

3.14 Appendages

3.14.1 The scantlings of appendages will be subject to special consideration on the basis of the Rules and the design loadings anticipated, but in no case are to be taken as less than that of the surrounding structure.

3.15 Fender attachment

3.15.1 Wood belting and fenders are to be bolted to lugs welded to a ground bar attached to the shell and not through-bolted to the shell plating.

3.16 Novel features

3.16.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculation. Such calculations are to be carried out on the basis of the Rules or recognized standards. Details are to be submitted for consideration.

■ *Section 4*
Shell envelope framing

4.1 General

4.1.1 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.1.2 For each stiffening member an assumed load model is stated. Where the proposed stiffener arrangement differs from that assumed, consideration will be given to an alternative load model.

4.1.3 The geometric properties of stiffener sections are to be in accordance with 1.18.

4.2 Bottom longitudinal stiffeners

4.2.1 Bottom longitudinal stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is proposed to terminate the bottom longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.3 Bottom longitudinal primary stiffeners

4.3.1 Bottom longitudinal primary stiffeners are to be supported by bottom deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.3.2 Bottom longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.4 Bottom transverse stiffeners

4.4.1 Bottom transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.5 Bottom transverse frames

4.5.1 Bottom transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.6 Bottom transverse web frames

4.6.1 Bottom transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is proposed to terminate the bottom transverse web frames in way of longitudinal primary girders bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.7 Side longitudinal stiffeners

4.7.1 The side longitudinal stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.7.2 Side longitudinals are to be continuous through the supporting structures.

4.7.3 Where it is impracticable to comply with the requirements of 4.7.2, or where it is proposed to terminate the side longitudinal in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.7.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.8 Side longitudinal primary stiffeners

4.8.1 Side longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.8.2 Side longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.8.3 Where it is impracticable to comply with the requirements of 4.8.2, or where it is proposed to terminate the side longitudinally in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.8.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.9 Side transverse stiffeners

4.9.1 Side transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

4.9.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.10 Side transverse frames

4.10.1 Side transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.10.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.11 Side transverse web frames

4.11.1 Side transverse web frames are defined as primary stiffening members which support side shell longitudinally. They are to be continuous and substantially bracketed at their head and heel connections to deck transverses and bottom web frames respectively.

4.11.2 Where it is impracticable to comply with the requirements of 4.11.1, or where it is proposed to terminate the web frames in way of side longitudinal primary stiffeners bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.11.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.12 Grouped frames

4.12.1 For the purposes of satisfying Rule scantling requirements, frames may, subject to agreement by LR, be grouped. The number of frames in any group shall not in general exceed five. The summation of the section moduli and inertia for the group of frames is not to be less than the summation of the Rule requirement for the individual framing members. In addition, in no case is the proposed scantling of an individual framing member within the group to be less than ninety per cent of the Rule value for that member.

4.13 Grillage structures

4.13.1 For complex girder systems, a complete structural analysis using numerical methods may have to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

4.13.2 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

4.13.3 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

4.14 Combined framing systems

4.14.1 Where longitudinal and transverse primary stiffeners form grillage structures the scantlings may be derived in accordance with 4.13.

4.15 Floating framing systems

4.15.1 Floating framing systems, where proposed, will be subject to special consideration.

4.16 Frame struts

4.16.1 Where struts are fitted to side shell transverse web frames or longitudinal primary stiffeners to carry axial loads, the strut cross-sectional area is to be derived as for pillars in Section 10. If fitted at the stiffener half span point the stiffener section modulus may be taken as half the modulus derived above.

4.16.2 Design of end connections is to be such that the area of the welding is to be not less than the minimum cross-sectional area of the strut derived in 4.16.1. To achieve this full penetration welding may be required. The weld connections between the face flats and webs of the pillar supporting structure are to be welded using double continuous welding of an equivalent area to that derived by 4.16.1.

4.17 Arrangements and details

4.17.1 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection are the section modulus and inertia reduced to less than that of the stiffener with associated plating.

4.17.2 The web stability, openings in the web and continuity and alignment are to be in accordance with 1.24, 1.25 and 1.26 respectively.

4.17.3 Secondary and primary end connections and arrangements at intersection of continuous secondary and primary members are to be in accordance with 1.20, 1.22 and 1.28 respectively.

4.17.4 Stiffeners in slamming areas are to be lugged or bracketed.

4.18 Structure in way of fenders

4.18.1 For craft, including pilot craft and fishing craft, which may be subject to repeated impact loadings from contact with other craft whilst in service, due consideration is to be given to increasing the scantlings of stiffening members in way of fenders. Details of anticipated loadings and calculations for the required increased scantlings are to be submitted, *see also* 3.6.3 and 3.6.4.

4.18.2 **Pilot craft** are to be fitted with large knees in way of the sheerstrake in areas as indicated in 3.6. The knees are to be aligned between the transverse frames and the deck beams. In the case of longitudinally framed craft, intermediate knees are to be fitted with a spacing in general not greater than 500 mm. Where such intermediate brackets are fitted they are to terminate on a side longitudinal with a section modulus of, in general, twice that of the Rule longitudinal for the web frame spacing, and a deck longitudinal. The side longitudinal is to be positioned below any fendering to carry the heel of the knee. Consideration will given to the termination of such brackets by use of a ‘soft-toe’ in way of the deck. The thickness of the webs for these knees is to be twice that required by 1.21.

4.18.3 **Fishing craft** engaged in pair trawling and other modes of fishing, and which may be subject to repeated impact loading from contact with the other craft are to have additional stiffening fitted in way of the impact areas. This may be in the form of large knees, intermediate knees, substantial fendering/ rubbing strakes.

4.19 Novel features

4.19.1 The scantlings are to be determined by direct calculation where the shell framing is of unusual design, form or proportions.

■ *Section 5*
Single bottom structure and appendages

5.1 General

5.1.1 The requirements of this Section provide for single bottom construction in association with transverse and longitudinal framing systems.

5.1.2 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

5.1.3 Particular attention is to be taken to ensure that the continuity of structural strength in way of the intersection of transverse floors and longitudinal girders is maintained. The face flats of such stiffening members are to be effectively connected.

5.1.4 The single bottom structure in way of the keel and girders is to be sufficient to withstand the forces imposed by dry-docking the craft.

5.1.5 The scantlings of the single bottom structure are to comply with the appropriate minimum requirements given in Section 2.

5.2 Keel

5.2.1 The breadth, and thickness of plate keels are to comply with the requirements of 3.2.

5.2.2 The cross-sectional area, A_k, and thickness, t_k, of bar keels are not, in general, be taken as less than:

$$A_k = k_a(1{,}85L_R + 2)\ \text{cm}^2$$

$$t_k = \sqrt{k_a}\,(0{,}7L_R + 8{,}25)\ \text{mm}$$

where

L_R and k_a are as defined in 1.5.1.

5.3 Centre girder

5.3.1 A centreline girder is, in general, to be fitted throughout the length of the hull in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders are to be formed of intercostal or continuous plate webs with a face flat welded to the upper edge. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement will be required to maintain the continuity of structural strength.

5.3.3 The web depth of the centre girder is, in general, to be equal to the depth of the floors at the centreline as specified in 5.5.3.

5.3.4 The web thickness, t_w, is to be taken not less than:

$$t_w = 1{,}4\sqrt{k_a}\left(\sqrt{L_R} + 1\right) \text{ mm}$$

where

L_R and k_a are as defined in 1.5.1.

5.3.5 The geometric properties of the centre girder are to be in accordance with 1.18.

5.3.6 The face flat area of the centre girder, A_f, is to be not less than:

$$A_f = 0{,}56 L_R k_a \text{ cm}^2$$

5.3.7 The face flat area of the centre girder outside $0{,}5L_R$ amidships may be 80 per cent of the value given in 5.3.6.

5.3.8 The face flat thickness is to be not less than the thickness of the web.

5.3.9 The ratio of the width to thickness of the face flat is to be not less than eight but should not exceed 16.

5.3.10 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 6,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The web thickness of side girders is to be taken as not less than:

$$t_w = 1{,}4\sqrt{k_a L_R} \text{ mm}$$

where

L_R and k_a are as defined in 1.5.1.

5.4.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in 5.5.6 and 5.5.7.

5.4.4 Watertight side girders, and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deeptanks as detailed in 7.3 and 7.5 respectively.

5.4.5 In the engineroom, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.4.6 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

5.5 Floors general

5.5.1 In transversely framed craft, plate floors are generally to be fitted at each frame.

5.5.2 In longitudinally framed craft, plate floors are to be fitted at every transverse web and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are in general to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft forward.

5.5.3 The overall depth, d_f, of plate floors at the centreline is not to be taken as less than:

when $B < 10$ m $\quad d_f = 40(B + 0{,}85D)$ mm

when $B \geq 10$ m $\quad d_f = 40(1{,}5B + 0{,}85D) - 200$ mm

where

D is defined in Pt 3, Ch 1,6.2.8.

5.5.4 The web thickness, t_w, of plate floors, is to be accordance with 1.18 and is to be taken as not less than:

$$t_w = \sqrt{k_a}\left(\frac{4{,}7d_f}{1000} + 3{,}1\right)\left(\frac{s}{1000} + 0{,}5\right) \text{ mm}$$

where

d_f is to be determined from 5.5.3

k_a and s are as defined in 1.5.1.

5.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.6 The face flat area of floors, A_f, is not to be taken as less than:

$$A_f = 0{,}28 k_a L_R \text{ cm}^2$$

where

k_a and L_R are defined in 1.5.1.

5.5.7 The face flat thickness is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than eight but is not to exceed 16.

5.5.8 Additionally the requirements of 4.6 for bottom transverse web frames are to be complied with.

5.5.9 Floors are generally to be continuous from side to side.

5.5.10 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.11 The floors in the aft peak are to extend over and provide effective support to the stern tube(s) where applicable.

5.5.12 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in 7.3 and 7.5.

5.6 Floors in machinery spaces

5.6.1 The thickness, t_w, of the floors in machinery spaces is to be 1 mm greater than that required by 5.5.4.

5.6.2 The depth and section modulus of floors anywhere between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The face flat area and web thickness for such reduced floor heights are to be increased appropriately in order to maintain continuity of structural strength, *see also* 4.12.

5.7 Machinery seatings

5.7.1 The general requirements for machinery seatings are given in Pt 3, Ch 2,6.9, *see also* Pt 9, Ch 1,5.

5.7.2 Engine holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders. When this cannot be achieved, bracket floors are to be fitted.

5.7.3 Welding in way of machinery seatings is to be double continuous and/or full penetration where appropriate.

5.8 Drainholes in bottom structure

5.8.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

5.8.2 Particular attention is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

5.8.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

5.9 Rudder horns

5.9.1 The shell plating thickness in way of the rudder horn is to be increased locally, by generally not less than 50 per cent but need not to be taken as greater than the keel thickness required by 3.2.

5.9.2 The scantlings of the rudder horn are to be such that the section modulus against transverse bending at any horizontal section XX (*see* Fig. 3.5.1) is not less than:

$$Z = 2{,}8 k_a\, R_A\, K_V\, (V + 3)^2 \sqrt{a^2 + 0{,}5 b^2} \quad \text{cm}^3$$

where

R_A = total rudder area, in m^2

V = Maximum speed in the fully loaded condition, in knots

K_V = 1,0 for displacement craft with $\dfrac{V}{\sqrt{L_{WL}}} < 3{,}0$

= $(1{,}12 - 0{,}005V)^3$ for planing and semi-planing craft with $\dfrac{V}{\sqrt{L_{WL}}} \geq 3{,}0$

a, b = dimensions, in metres, as given in Fig. 3.5.1

L_{WL} = waterline length as defined in Pt 3, Ch 1,6.2.5.

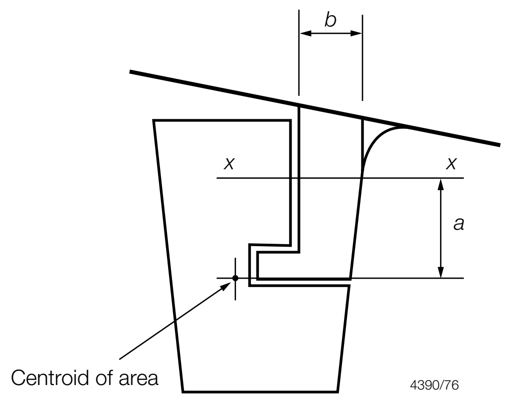


Fig. 3.5.1 Rudder horn

5.9.3 Rudder horns are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

5.10 Sternframes

5.10.1 The scantlings of fabricated and forged/solid sternframes are to comply with the requirements of Pt 3, Ch 3,3 modified for appropriate grade of aluminium in accordance with Pt 3, Ch 3,1.2.

5.11 Skeg construction

5.11.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

5.11.2 The scantlings and arrangements for skegs (solepieces) are to be in accordance with Pt 3, Ch 3,3.14.

5.11.3 The scantlings of skegs are to be sufficient to withstand any docking forces that they may be subjected to.

5.12 Forefoot and stem

5.12.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 3.2.

5.12.2 The forefoot and stem is to be additionally reinforced with floors.

5.12.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than:

$$A_{bs} = 1{,}5k_a L_R \text{ cm}^2$$

where

L_R and k_a are as defined in 1.5.1.

5.13 Transom knee

5.13.1 Centre and side girders are to be bracketed to the transom framing members by means of substantial knees. The face flat of the girders may be gradually reduced to that of the transom stiffening members in accordance with Fig. 3.5.2.

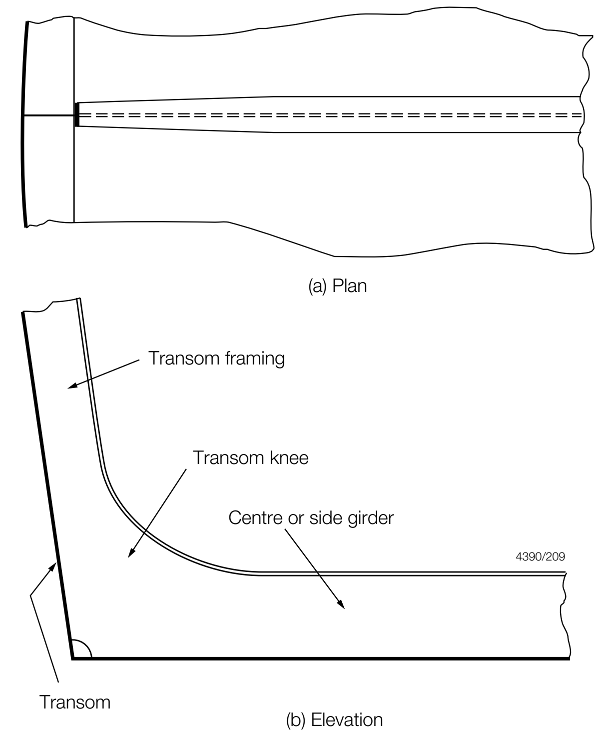


Fig. 3.5.2 Transom knee

5.13.2 Hard spots are to be avoided in way of the end connections and care is to be taken to ensure that the stiffening member to which the transom knee is bracketed can satisfactorily carry the transmitted loads.

Section 6
Double bottom structure

6.1 General

6.1.1 The requirements given in this Section provide for double bottom construction of aluminium mono-hull craft in association with either transverse or longitudinal framing.

6.1.2 Double bottoms are generally to be fitted in accordance with Pt 3, Ch 2,6.6 and where fitted are to extend from the collision bulkhead to the after peak bulkhead, as far as this is practicable within the design and proper working of the craft. In addition, the inner bottom is to be continued to the craft's side in such a manner as to protect the bottom to the turn of bilge or chine.

6.1.3 The double bottom structure in way of girders and duct keels is to be sufficient to withstand the forces imposed by dry-docking the craft.

6.1.4 The centreline girder and side girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

6.1.5 The scantlings of the double bottom structure are to comply with the appropriate minimum requirements given in Section 2.

6.2 Keel

6.2.1 The scantlings of bar and plate keels are to comply with the requirements of 5.3.

6.2.2 Duct keels, where arranged, are to have a side plate thickness not less than:

$$t = \sqrt{k_a}\,(0{,}01d_{DB} + 2) \text{ mm}$$

but need not be taken as greater than 90 per cent of the centre girder thickness given in 6.3.

d_{DB} is the Rule centre girder depth given in 6.3.3

k_a is as defined in 1.5.1.

6.2.3 Where a duct keel forms the boundary of a tank, the requirements of 7.4 and 7.5 for deep tanks are to be complied with.

6.2.4 The duct keel width is in general to be 15 per cent of the beam or 2 m, whichever is the lesser, but in no case is it to be taken as less than 630 mm. The inner bottom and bottom shell within the duct keel are to be suitably stiffened with primary stiffening in the transverse direction, whilst the continuity of the floors is maintained. Access to the duct keel is to be by means of watertight manholes or trunks.

6.3 Centre girder

6.3.1 A centre girder is to be fitted throughout the length of the craft. The web thickness, t_w, is not to be less than that required by:

$t_w = \sqrt{k_a}$ (0,14L_R + 4) mm within 0,4L_R amidships
$= \sqrt{k_a}$ (0,14 L_R + 2,75) mm at ends.

where
k_a and L_R are as defined in 1.5.1.

6.3.2 The geometric properties of the girder section are to be in accordance with 1.18.

6.3.3 The overall depth of the centre girder, d_{DB}, is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the floor breadth does not exceed 6,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 6,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 3,0 m.

6.4.3 Side girders where fitted are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness of non-watertight plate floors, t_w, is to be not less than:

$t_w = \sqrt{k_a}$ (0,07L_R + 4,75) mm

where
k_a and L are as defined in 1.5.1.

6.5.2 Additionally, the requirements of 4.6 for bottom transverse web frames stiffeners are to be complied with.

6.5.3 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.4 In longitudinally framed craft, plate floors or equivalent structure are in general to be fitted in the following positions:
(a) At every half frame in way of the main engines, thrust bearings and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engine room.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.5 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than 10t_w and a thickness of not less than t_w, where t_w is thickness of the plate floor as calculated in 6.5.1.

6.5.6 In transversely framed craft, plate floors are to be fitted at every frame in the engine room, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Bracket floors

6.6.1 Between plate floors, the shell and inner bottom plating is to be supported by bracket floors. The brackets are to have the same thickness as plate floors and are to be stiffened on the unsupported edge.

6.6.2 In longitudinally framed craft, the brackets are to extend from the centre girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket to be taken as not less than 75 per cent of the depth of the centre girder. They are to be fitted at every web frame at the margin plate, and those at the centre girder are to be spaced not more than 1,0 m apart.

6.6.3 In transversely framed craft, the breadth of the brackets, attaching the bottom and inner bottom frames to the centre girder and margin plate, is to be not less than 75 per cent of the depth of the centre girder.

6.7 Watertight floors

6.7.1 The scantlings of watertight floors are to comply with the requirements for plate floors as given in 6.5.

6.7.2 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3 or 7.5 respectively.

6.8 Tankside brackets

6.8.1 The scantlings of tankside brackets are to comply with the requirements for plate floors given in 6.5.

6.9 Inner bottom plating

6.9.1 The thickness of the inner bottom plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

6.9.2 Inner bottom plating forming the boundaries of tank spaces is, in addition, to comply with the requirements for watertight bulkheads or deeptanks as detailed in 7.2 or 7.4 respectively. Where the plating forms vehicle, passenger or other decks the requirements of Section 8 are to be complied with.

6.9.3 Inner bottom longitudinals are to be supported by inner bottom transverse web frames, floors, bulkheads or other primary structure, generally spaced not more than 2 m apart.

6.9.4 The inner bottom longitudinals are to be continuous through the supporting structure and are to be satisfactorily stiffened against buckling.

6.9.5 Where it is impracticable to comply with the requirements of 6.9.4, or where it is desired to terminate the inner bottom longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.9.6 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

6.10 Inner bottom transverse web framing

6.10.1 Inner bottom transverse web frames are defined as primary stiffening members which support inner bottom longitudinals. They are to be continuous and to be substantially bracketed at their end connections to bottom web frames, bottom floors and tankside brackets.

6.10.2 Where it is impracticable to comply with the requirements of 6.10.1, or where it is desired to terminate the inner bottom transverse web frames in way of centre or side girders, bulkheads or integral tank boundaries, etc., they are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.10.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

6.11 Margin plates

6.11.1 A margin plate, if fitted, is to have a thickness as required for inner bottom plating.

6.12 Wells

6.12.1 Small wells constructed in the double bottom structure are not to extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted at the after end of the shaft tunnel of the craft. Other well arrangements (e.g. for lubricating oil under main engines) may be considered provided they give protection equivalent to that afforded by the double bottom.

6.13 Transmission of pillar loads

6.13.1 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided, and where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

6.14 Manholes

6.14.1 Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to, and ventilation of, all parts of the double bottom. The size of the manhole openings is not, in general, to exceed 50 per cent of the double bottom depth unless edge reinforcement is provided. Holes are not to be cut in the centre girder, except in tanks at the forward and after ends of the craft, and elsewhere where tank widths are reduced unless additional stiffening and/or compensation is fitted to maintain the structural integrity.

6.15 Pressure testing

6.15.1 Double bottoms are to be tested upon completion with a head of water representing the maximum internal pressure which could be experienced in service, but not less than a head of water equivalent to the level of the upper deck.

6.16 Drainholes in bottom structure

6.16.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

6.16.2 Particular care is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

6.16.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

■ *Section 7* Bulkheads

7.1 General

7.1.1 The requirements of this Section apply to a vertical system of stiffening on bulkheads. They may also be applied to a horizontal system of stiffening provided that equivalent support and alignment are provided.

7.1.2 The number and disposition of transverse watertight bulkheads are to be in accordance with Pt 3, Ch 2,4.

7.1.3 Bulkheads, or part bulkheads, forming the boundary of tanks are to comply with the requirements of 7.5 and 7.6.

7.1.4 For bulkheads in way of partially filled holds or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

7.1.5 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to comply with the requirements of 7.5 and 7.6 for tank boundary bulkheads. If perforated, they are to comply with the requirements of 7.13 for washplates.

7.1.6 The minimum requirements in Section 2 are to be complied with.

7.2 Watertight bulkhead plating

7.2.1 The thickness of the watertight bulkhead plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5 Ch 4,3.1 for non-displacement or displacement craft as appropriate.

7.3 Watertight bulkhead stiffening

7.3.1 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 using the appropriate load model.

7.3.2 Bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.4 Deep tank plating

7.4.1 The thickness of deep tank plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

7.5 Deep tank stiffening

7.5.1 Deep tank bulkhead stiffeners are to be bracketed at both ends. The thickness of the brackets is to be not less than the web thickness of the stiffener.

7.5.2 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for load model (b).

7.6 Double bottom tanks

7.6.1 The scantlings of double bottom tanks are to comply with the requirements for deep tanks given in 7.4 and 7.5.

7.6.2 Where the crown of a double bottom tank forms a vehicle, passenger or other deck, the requirements of Section 8 are to be complied with.

7.7 Collision bulkheads

7.7.1 The scantlings of collision bulkheads are to comply with the requirements of 7.2 and 7.3 except that the thickness of plating and modulus of stiffeners are not to be less than 12 and 25 per cent greater respectively, than required by 7.2 and 7.3. If the collision bulkhead forms the boundary of a deep tank or cofferdam then the requirements of 7.4 and 7.5 are also to be complied with.

7.8 Gastight bulkheads

7.8.1 Where gastight bulkheads are fitted, in accordance with Pt 3, Ch 2,4 the scantling requirements for watertight bulkheads are to be complied with.

7.8.2 Gastight bulkheads are to be fitted to protect accommodation spaces from gases and vapour fumes from machinery exhaust and fuel systems.

7.9 Non-watertight or partial bulkheads

7.9.1 Where a bulkhead is structural but non-watertight the scantlings are in general to be as for watertight bulkheads or equivalent in strength to web frames in the same position. Partial bulkheads that are non-structural are outside the scope of classification.

7.10 Transmission of pillar loads

7.10.1 Bulkheads that are required to act as pillars in way of underdeck girders and other structures subject to heavy loads are to comply with the requirements of Section 10.

7.11 Corrugated bulkheads

7.11.1 The plating thickness and section modulus for symmetrical corrugated bulkheads are to be in accordance with watertight bulkheads or deep tank bulkheads as appropriate. The spacing, s, is to be taken as s_C, as defined in Fig. 2.3.1 in Pt 3, Ch 2.

7.11.2 In addition, the section geometric properties of 1.18 are to be complied with.

7.11.3 The actual section modulus may be derived in accordance with Pt 3, Ch 2,3.2.

7.12 Stiffeners passing through bulkheads

7.12.1 Primary longitudinal stiffening members are to be continuous through transverse bulkheads.

7.12.2 Pipe or cable runs through watertight bulkheads are to be fitted with suitable watertight glands.

7.13 Wash plates

7.13.1 Tanks are to be subdivided as necessary by internal baffles or wash plates. Baffles or wash plates which support hull framing are to have scantlings equivalent to web frames in the same position.

7.13.2 Wash plates and wash bulkheads are, in general, to have an area of perforation not less than 10 per cent of the total area of the bulkhead. The perforations are to be so arranged that the efficiency of the bulkhead as a support is not impaired.

7.13.3 The plate thickness is to be not less than the structural element from which the wash bulkhead is formed.

7.13.4 The general stiffener requirements are to be in accordance with 7.5. However, the section modulus may be 50 per cent of that required by 7.5.

7.14 Cofferdams

7.14.1 A cofferdam is to be fitted between freshwater and oil fuel or sanitary tanks.The scantlings of cofferdams are to comply with the requirements of deep tank bulkheads or non-watertight bulkheads as appropriate.

7.15 Coatings

7.15.1 Integral freshwater and oil fuel tanks need not in general be coated provided they are constructed from suitable marine grade aluminium alloys in accordance with Pt 2, Ch 8. Where tanks are to be coated, then all surfaces are to be cleaned and dried after testing and then treated with a suitable coating in accordance with the coating manufacturer's recommendations. *See* Pt 7, Ch 2,2.6.

7.16 Air pipes

7.16.1 Air pipes of sufficient number and area are to be fitted to each tank in accordance with Pt 15, Ch 2,11.

7.17 Fire protection

7.17.1 Fire protection requirements given in Part 17 are to be complied with.

7.18 Access

7.18.1 Compartments within the craft are to be accessible in order to facilitate proper maintenance and future structural surveys. Linings on craft sides, deckheads and bulkheads, etc., must be capable of being removed. Similarly sufficient space must be available below lower decks/soles to provide proper access to the bottom structure. An adequate number of manholes, removable panels etc. are to be provided.

7.18.2 Doors and hatches fitted through watertight bulkheads are to be of equivalent construction to the bulkhead in which they are fitted, to be permanently attached and capable of being closed watertight from both sides of the bulkhead. They are to be tested watertight.

7.18.3 Doors and hatches are not to be fitted in collision bulkheads, except in craft of less than 21 m Rule length or where it would be impracticable to arrange access to the fore-peak other than through the collision bulkhead. Where fitted, the doors and hatches are to be watertight, as small as practicable and open into the forepaw compartment. Doors in collision bulkheads are to be kept closed at all times while the craft is at sea, *see* Pt 3, Ch 2,4.3.4.

7.18.4 Particular attention is to be given to the design and workmanship of the tanks, and adequate access manholes are to be fitted, *see* Pt 3, Ch 1,7.

7.19 Testing

7.19.1 Deep tanks are to be tested on completion, with a head of water to the top of the overflow, or 1,8 m above the crown of the tank, whichever is the greater, The pressure to which the tanks will be subjected in service is to be indicated on the plans submitted.

■ *Section 8* Deck structures

8.1 General

8.1.1 The deck plating is to be supported by transverse beams with fore and aft girders or by longitudinals with deep transverse beams. The transverse and deep transverse beams are to align with side main frames and side web frames respectively.

8.1.2 Beams are to be fitted at every frame and bracketed to the frames. Strong beams and deep transverse beams are to align with and be effectively connected to the side web frames. They are also to be fitted at the ends of large openings in the deck.

8.1.3 The deck plating and supporting structure are to be suitably reinforced in way of cranes, masts, derrick posts and deck machinery.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Primary and secondary stiffener end connection arrangements are, in general, to be in accordance with 1.22 and 1.20, respectively.

8.1.7 The ends of beams, longitudinals, girders and transverses are to be effectively built into the adjacent structure, or equivalent arrangements provided.

8.1.8 Tripping brackets are to be fitted on deep webs.

8.1.9 Deck structures subject to concentrated loads, are to be suitably reinforced. Where concentrations of loading on one side of a stiffening member may occur, such as pillars out of line, the member is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

8.1.10 The thickness of the deck plating is in no case to be less than the appropriate minimum requirement given in Section 2.

8.1.11 The geometric properties of stiffener sections are to be in accordance with 1.18.

8.2 Strength/weather deck plating

8.2.1 The thickness of strength/weather deck plating is to be determined from the general plating equation given in 1.16 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.2.2 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck. *See also* Part 4.

8.2.3 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.2.4 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted. *See also* 2.4.

8.3 Lower deck/inside deckhouse plating

8.3.1 The thickness of the lower deck/inside deckhouse plating is to be determined from the general plating equation given in 1.16 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.4 Accommodation deck plating

8.4.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their plating requirements determined in accordance with 8.3.

8.5 Cargo deck plating

8.5.1 The thickness of cargo deck plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.5.2 For vehicle decks, the plating thickness is to comply with the requirements of Ch 5,3.

8.6 Decks forming crowns of tanks

8.6.1 Decks forming the crown of tanks are to comply with the requirements for the appropriate deck, and are to be additionally examined for compliance with the requirements for deep tank plating given in 7.4.

8.7 Strength/weather deck stiffening

8.7.1 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck primary stiffening** are to be determined from the general equations given in 1.17, using the design pressure heads from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

8.7.2 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.7.3 Longitudinal framing is, in general, to be adopted at the strength deck outside line of openings, but special consideration will be given to proposals for transverse framing.

8.8 Lower deck/inside deckhouse stiffening

8.8.1 The Rule requirements for section modulus, inertia and web area for lower deck/inside deckhouse stiffening are to be determined from the general equations given in 1.17 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.9 Accommodation deck stiffening

8.9.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with 8.8.

8.10 Cargo deck stiffening

8.10.1 The Rule requirements for section modulus, inertia and web area for cargo deck stiffening are to be determined from the general equations given in 1.17 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.10.2 In addition, where the cargo comprises wheeled vehicles, the requirements of Ch 5,3 are to be complied with.

8.11 Deck openings

8.11.1 All openings are to be supported by an adequate framing system, pillars or cantilevers. When cantilevers are used scantlings may be derived from direct calculations.

8.11.2 Where stiffening members terminate in way of an opening they are to be attached to carlings, girders, transverses or coaming plates.

8.11.3 The corners of large hatchways in the strength/weather deck within $0,5L_R$ amidships are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.4 Where elliptical corners are arranged, the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than two to one nor greater than 2,5 to one, and the minimum half-length of the major axis is to be defined by l_1 in Fig. 3.8.1. Where parabolic corners are arranged, the dimensions are also to be as shown in Fig. 3.8.1.

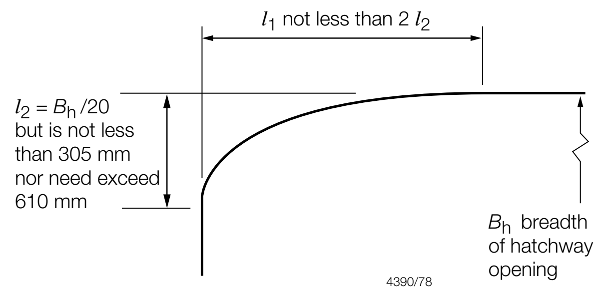


Fig. 3.8.1 Hatch opening geometry

8.11.5 Where the corners are parabolic or elliptical, insert plates are not required.

8.11.6 For other shapes of corner, insert plates of the size and extent shown in Fig. 3.8.2 will, in general, be required. The required thickness of the insert plate is to be not less than 25 per cent greater than the adjacent deck thickness, outside line of openings.

8.11.7 For lower decks the corners of large openings are to be rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.8 Insert plates will be required at lower decks in way of any rapid change in hull form to compensate for loss of deck cross-sectional area. Otherwise, insert plates will not normally be required.

8.11.9 Adequate transverse strength is to be provided in the deck area between large hatch openings, subjected to transverse and buckling loads.

8.11.10 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

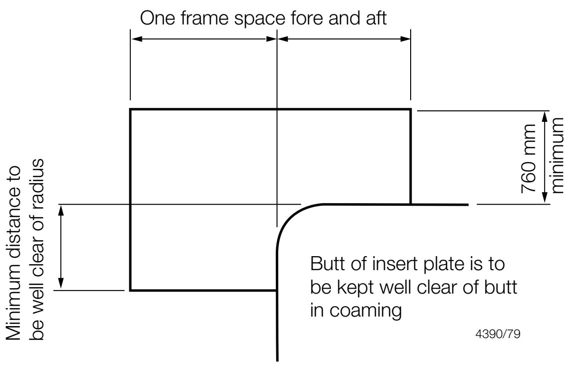


Fig. 3.8.2 Inserts in way of hatch opening

8.12 Sheathing

8.12.1 The requirements for deck sheathing given in 2.4 are to be complied with.

8.13 Novel features

8.13.1 Where large or novel hatch openings are proposed, detailed calculations are to be submitted to demonstrate that the scantlings and arrangements in way of the openings are adequate to maintain continuity of structural strength.

■ *Section 9* Superstructures, deckhouses and bulwarks

9.1 General

9.1.1 Where practicable, superstructures and deckhouses are to be designed with well cambered decks and well radiused corners to build rigidity into the structure.

9.1.2 The plating and supporting structure are to be suitably reinforced in way of localised areas of high stress such as corners of openings, cranes, masts, derrick posts, machinery, fittings and other heavy or vibrating loads.

9.1.3 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

9.1.4 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

9.1.5 Structures subject to concentrated loads are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, such as pillars out of line, the stiffener is to be adequately stiffened against torsion.

9.1.6 The plating thickness of superstructures, deckhouses and bulwarks is in no case to be less than the appropriate minimum requirement given in Section 2.

9.1.7 Stiffener sections and geometric properties are to be in accordance with 1.18.

9.2 Symbols and definitions

9.2.1 The term ‘house’ is used in this Section to include both superstructures and deckhouses.

9.2.2 The symbols applicable to this Section are defined in 1.5.1.

9.3 House side plating

9.3.1 The thickness of house side plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.4 House front plating

9.4.1 The thickness of the house front plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4, 3.1 for non-displacement or displacement craft as appropriate.

9.5 House end plating

9.5.1 The thickness of the house end plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.6 House top plating

9.6.1 The thickness of the house top plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.7 Coachroof plating

9.7.1 The thickness of the coachroof plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.8 Machinery casing plating

9.8.1 The thickness of the plating of machinery casings is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.9 Forecastle requirements

9.9.1 The forecastle side plating may be a continuation of the hull side shell plating or fitted as a separate assembly. In both cases the plating thickness is to be the same as the side shell plating at deck edge. Where fitted as a separate assembly, suitable arrangements are to be made to ensure continuity of the effect of the sheerstrake at the break and at the upper edge of the forecastle side. Full penetration welding is to be used.

9.9.2 The side plating is to be stiffened by side frames effectively connected to the deck structure. Deep webs are to be fitted to ensure overall rigidity.

9.9.3 The deck plating thickness is to be increased by 20 per cent in way of the end of the forecastle if this occurs at a position aft of $0,25L_R$ from the F.P. No increase is required if the forecastle end bulkhead lies forward of $0,2L_R$ from the F.P. The increase at intermediate positions of end bulkhead is to be obtained by interpolation.

9.10 House side stiffeners

9.10.1 The Rule requirements for section modulus, inertia and web area for the **house side primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.10.2 The Rule requirements for section modulus, inertia and web area for **house side secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.11 House front stiffeners

9.11.1 The Rule requirements for section modulus, inertia and web area for **house front primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.11.2 The Rule requirements for section modulus, inertia and web area for **house front secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.12 House aft end stiffeners

9.12.1 The Rule requirements for section modulus, inertia and web area for **house aft end primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.12.2 The Rule requirements for section modulus, inertia and web area for **house aft end secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.13 House top stiffeners

9.13.1 The house top is to be effectively supported by a system of transverse or longitudinal beams and girders. The span of the beams is in general not to exceed 2,4 m and the beams are to be effectively connected to the house upper coamings and girders.

9.13.2 The Rule requirements for section modulus, inertia and web area for **house top primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.13.3 The Rule requirements for section modulus, inertia and web area for house top **secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.14 Coachroof stiffeners

9.14.1 The Rule requirements for section modulus, inertia and web area for coachroof **primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.14.2 The Rule requirements for section modulus, inertia and web area for coachroof **secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15 Machinery casing stiffeners

9.15.1 The Rule requirements for section modulus, inertia and web area for machinery casing **primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.15.2 The Rule requirements for section modulus, inertia and web area for machinery casing **secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15.3 Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably reinforced.

9.15.4 Where casing sides act as girders supporting decks over, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular attention is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

9.16 Forecastle stiffeners

9.16.1 The scantlings of forecastle primary and secondary stiffening members are to be equivalent to those for the side shell envelope framing at the deck edge as required by Section 4.

9.17 Superstructures formed by extending side structures

9.17.1 Superstructure first tier sides formed by extending the hull side structure are to be in accordance with the requirements for house fronts given in 9.4 and 9.11 for plating and stiffeners respectively, but need not be taken as greater than the side structure requirements at the deck edge at the same longitudinal position.

9.18 Fire aspects

9.18.1 The requirements for fire detection, protection and extinction are given in Part 17.

9.19 Openings

9.19.1 All openings are to be substantially framed and have well rounded corners. Arrangements are to be made to minimise the effect of discontinuities in erections. Continuous coamings or girders are to be fitted below and above doors and similar openings.

9.19.2 Particular attention is to be paid to the effectiveness of end bulkheads, and the upper deck stiffening in way, when large openings for doors and windows are fitted.

9.19.3 Special care is to be taken to minimise the size and number of openings in the side bulkheads in the region of the ends of erections within $0,5L_R$ amidships. Account is to be taken of the high vertical shear loading which can occur in these areas.

9.19.4 For closing arrangements and outfit the requirements are given in Pt 3, Ch 4.

9.20 Mullions

9.20.1 Window openings are to be suitably framed and mullions will in general be required.

9.20.2 The scantlings of mullions are to be not less than as required for a stiffener in the same position.

9.20.3 When determining the stiffener requirements, the width of effective plating is in no case to be taken as greater than the distance between adjacent window openings.

9.20.4 Where significant shear forces are to be vertically transmitted by the window frames, adequate shear rigidity is to be verified by direct calculation.

9.21 Global strength

9.21.1 Transverse rigidity is to be maintained throughout the length of the erection by means of web frames, bulkheads or partial bulkheads. Particular attention is to be paid when an upper tier is wider than its supporting tier and when significant loads are carried on the house top.

9.21.2 Where practicable, web frames are to be arranged in line with bulkheads below.

9.21.3 Internal bulkheads are to be fitted in line with bulkheads or deep primary stiffeners below.

9.22 House/deck connection

9.22.1 Adequate support under the ends of erections is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams.

9.22.2 Special attention is to be given to the connection of the erection to the deck in order to provide an adequate load distribution and avoid stress concentrations.

9.22.3 Connections between the erection and the deck by means of bimetallic joints are to comply with Ch 2,4.31.

9.22.4 Typical design details of house/deck connections are given in LR's *Guidance Notes for Structural Details*.

9.23 Sheathing

9.23.1 Sheathing arrangements are to comply with the requirements of 2.4.

9.24 Erections contributing to longitudinal strength

9.24.1 For craft above 40 m in length, L_R, or for designs where the superstructure is designed to absorb global loads the effectiveness of superstructures to carry these loads is to be determined. The effectiveness may be assessed in accordance with Ch 6,2.5.

9.24.2 Where 9.17 applies and the first or second tier is regarded as the strength deck according to Ch 6,2.5, the hull upper deck scantlings at the forward and aft ends of the superstructure may need to be increased due to the lesser efficiency of the superstructure tiers at their ends. The scantlings of the side structure in way of these areas may also need to be increased.

9.24.3 When large openings or a large number of smaller openings are cut in the superstructure sides, reducing the capability to transmit shear force between decks, an assessment or structural efficiency may be required.

9.25 Novel features

9.25.1 Direct calculations may be required to determine the plating and stiffener requirements where the house is of unusual design, form or proportions.

9.26 Bulwarks

9.26.1 General requirements for bulwarks are given in Pt 3, Ch 4,8.

9.26.2 The thickness of the bulwark plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (d).

9.26.4 Bulwarks are not to be cut for gangway or other openings near the breaks of superstructures.

9.26.5 Attention is to be paid to avoid discontinuity of strength of the bulwark, particularly in way of local increases in stress and changes in height.

9.26.6 Welding of bulwark to the top edge of sheer strake within $0,5L_R$ amidship, is generally to be avoided. However, if this arrangement is not practicable welding to the sheerstrake may be accepted if care is taken to minimise any notch effects.

9.26.7 **Fishing craft** are to have bulwarks fitted. The bulwark may be formed from a continuation of the side shell plating or connected as a separate assembly. Where the bulwark is considered to be stressed and contributing to the global strength of the craft, the plate thickness of the bulwark is not to be less than the sheerstrake plating thickness. In no case is the thickness of the bulwark plating to be taken as less than 80 per cent of the side shell thickness. The bulwark is to be supported by suitable stiffening members which may be formed from a continuation of the side frames, or from flanged plate stays of the same thickness as the bulwark. In general these frames are to be spaced not more than two side frame spacings apart.

9.26.8 In way of gantries, trawl gallows, mooring pipes, etc., the plate thickness in way is to be increased by not less than 50 per cent.

9.26.9 **Pilot craft** are to be fitted with sufficient hand rails adjacent to the exposed areas of the working decks and platforms. In addition these areas are to have non-skid surfaces.

9.27 Freeing arrangements

9.27.1 Requirements for freeing arrangements are given in Pt 3, Ch 4,9.

9.28 Free flow area

9.28.1 The requirements for the free flow area are given in Pt 3, Ch 4,9.3.

9.29 Guard rails

9.29.1 The requirements for guard rails are given in Pt 3, Ch 4,8.4.

Section 10
Pillars and pillar bulkheads

10.1 Application

10.1.1 Pillars are to be arranged to transmit loads from decks and superstructures into the bottom structure. Pillars are generally to be constructed from solid, tubular, or I beam section. A pillar may be a fabricated trunk or partial bulkhead.

10.2 Determination of span length

10.2.1 The effective span length of the pillar, l_{ep}, is in general the distance between the head and heel of the pillar. Where substantial brackets are fitted, l_{ep} may be reduced by 2/3 the depth of the bracket at each end.

10.3 Head and heel connections

10.3.1 Pillars are to be attached at their heads to plates supported by efficient brackets, in order to transmit the load effectively. Doubling or insert plates are to be fitted to decks under large pillars and to the inner bottom under the heels of tubular or hollow square pillars. The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be well distributed by means of longitudinal and transverse brackets.

10.4 Alignment and arrangement

10.4.1 Pillars are to be located on main structural members. They are in general to be fitted below windlasses, winches, capstans, the corners of deckhouses and elsewhere where considered necessary.

10.4.2 Wherever possible, deck pillars are to be fitted in the same vertical line as pillars above and below, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

10.4.3 Where pillars support eccentric loads, or are subjected to lateral pressures, they are to be suitably strengthened for the additional bending moment imposed upon them.

10.4.4 Doublers are generally to be fitted on decks and inner bottoms, other than within tanks where doublers are not allowed. Brackets may be used instead of doublers.

10.5 Minimum thickness

10.5.1 The minimum wall thickness of hollow pillars is to be taken as not less than 1/20 of the external dimension of the pillar.

10.6 Design loads

10.6.1 The design loading, P_p, is not to be less than:

$$P_p = S_{gt}\, b_{gt}\, P_c + P_a \quad \text{kN}$$

where

P_p = design load supported by the pillar, to be taken as not less than 5 kN

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over

S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillar, in metres.

10.7 Scantlings determination

10.7.1 The cross-sectional area of the pillar, A_p, is not to be less than:

$$A_p = 10\,\frac{P_p}{\sigma_p} \quad \text{cm}^2$$

where

P_p = design load, in kN, supported by the pillar as determined from 10.6

σ_p = permissible compressive stress, in N/mm^2

$$= \frac{f_p\,\sigma_A}{1 + 0{,}015\sigma_A\, k_f \left(\frac{l_{ep}}{r}\right)^2} \quad \text{N/mm}^2$$

where

f_p = pillar location factor defined in Table 3.10.1

σ_A = 0,2 per cent proof stress of the alloy in the unwelded condition, in N/mm^2

k_f = pillar end fixity factor
= 0,25 for full fixed/bracketed
= 0,50 for partially fixed
= 1,0 for free ended

r = least radius of gyration of pillar cross-section, in cm, and may be taken as:

$$r = \sqrt{\frac{I_p}{A_p}} \quad \text{cm}$$

I_p = least moment of inertia of cross-section of pillar or stiffener/plate combination, in cm^4

l_{ep} = effective span of pillar or bulkhead, in metres, as defined in 10.2.

Table 3.10.1 Pillar location factors

Location	f_p
Supporting weather deck	0,50
Supporting vehicle deck	0,50
Supporting passenger deck	0,50
Supporting lower/inner deck	0,75
Supporting coachroof	0,75
Supporting deckhouse top	1,00

10.8 Maximum slenderness ratio

10.8.1 The slenderness ratio (l_{ep}/r) of pillars is not to be taken greater than 1,1, where l_{ep} and r are as defined in 10.7.1. Pillars with slenderness ratio in excess of 1,1 may be accepted subject to special consideration on a case by case basis and provided that the remaining requirements of the Rules are complied with.

10.9 Pillars in tanks

10.9.1 In no circumstances are pillars to pass through tanks. Where loads are to be transmitted through tanks, pillars within the tanks are to be carefully aligned with the external pillars.

10.9.2 Pillars within tanks are, in general, to be of solid cross section. Where it is proposed to use hollow section pillars each case will be subject to special consideration and the scantlings as determined from the Rules may require to be increased dependent upon the material to be used, the fluid contained and the arrangement of the pillars. Hollow pillars are to be adequately drained and vented.

10.9.3 Where pillars within tanks may be subjected to tensile stresses due to hydrostatic pressure, the design is to provide sufficient welding to withstand the tensile load imposed.

10.9.4 Doubling plates at ends of pillars within tanks are not acceptable.

10.10 Pillar bulkheads

10.10.1 The stiffener/plate combination used in the determination of pillar bulkhead scantlings is to be that of a stiffener with an effective width of attached plating as determined from 1.11.

10.10.2 The cross-sectional area of the pillar bulkhead, A_{pb}, is to be determined in accordance with 10.7 using the design loading, P_{pb}, as follows:

$$P_{pb} = S_{bs}\, b_{pb}\, P_c + P_a \text{ kN}$$

where

P_{pb} = design load supported by the stiffener plate combination of the pillar bulkhead

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

S_{bs} = spacing, or mean spacing, of bulkheads or effective transverses/longitudinal stiffeners, in metres

b_{pb} = distance between centres of two adjacent spans of girders or transverses supported by the pillar bulkhead, in metres, and can be taken as the distance between pillar bulkhead stiffeners where the stiffeners at the top of the bulkhead effectively distributes the load evenly into the stiffeners.

10.10.3 The thickness of the bulkhead plating is in no case to be taken less than 4 mm.

10.11 Direct calculations

10.11.1 As an alternative to 10.6, pillars may be designed on the basis of direct calculation. The method adopted and the stress levels proposed for the material of construction are to be submitted together with the calculations for consideration.

10.12 Fire aspects

10.12.1 Pillars and pillar bulkheads are to be suitably protected against fire, and, where necessary, be self-extinguishing or capable of resisting fire damage. All pillars are to comply with the requirements of Part 17.

10.13 Novel features

10.13.1 Where unusual or novel pillar designs are proposed that are unable to comply with the requirements of this Section, their design together with the direct calculations are to be submitted for special consideration.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to multi-hull craft of aluminium construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 Except as otherwise specified within this Chapter, the scantlings and arrangements of multi-hull craft are to be determined in accordance with the procedures described in, or required by Chapter 3 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hulls.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,3.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

k_a = alloy factor
= $125/\sigma_a$

s = stiffener spacing, in mm

t_p = plating thickness, in mm

L_R = Rule length of craft, in metres

σ_a = 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2.

1.5.2 **Bottom outboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom outboard shell is defined as the area of the hull between the outboard edge of the keel and the outer bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom outboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.3 **Bottom inboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom inboard shell is defined as the area of the hull between the inboard edge of the keel and the inner bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom inboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.4 **Cross-deck.** The cross-deck is defined as the structure which forms the bridge connection between any two adjacent hulls.

1.5.5 **Haunch.** The haunch is defined as the transition area between the cross-deck and the inboard side shell plating.

1.5.6 **Side inboard.** The side inboard is defined as the area between the bottom inboard shell and the wet-deck (or lower edge of the haunches, where fitted).

1.5.7 **Side outboard.** The side outboard is defined as the area between bottom outboard shell and the deck at side.

1.5.8 **Wet-deck.** The wet-deck is defined as the area between the upper edges of the side inboard plating (or upper edges of the haunches, where fitted).

■ *Section 2* Minimum thickness requirements

2.1 General

2.1.1 Unless otherwise specified in this Section, the requirements of Ch 3,2 are to be complied with.

2.1.2 The thickness of plating and stiffeners determined from the Rule requirements is in no case to be less than the appropriate minimum requirement given in Table 4.2.1 for craft type.

2.1.3 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy global strength requirements.

Table 4.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Catamaran	Multi-hull	Swath
Shell envelope			
Bottom shell plating	$\omega \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\,\omega$	$\omega \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\,\omega$	$\omega \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\,\omega$
Side shell plating	$\omega \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$	$\omega \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$	$\omega \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$
Wet-deck plating	$\omega \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$	$\omega \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$	$\omega \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$
Single bottom structure			
Centre girder web	$\omega \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\,\omega$	$\omega \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\,\omega$	$\omega \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\,\omega$
Floor webs	$\omega \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\,\omega$	$\omega \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\,\omega$	$\omega \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\,\omega$
Side girder webs	$\omega \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\,\omega$	$\omega \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\,\omega$	$\omega \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\,\omega$
Double bottom structure			
Centre girder			
(1) Within 0,4*L* amidships	$\omega \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\,\omega$	$\omega \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\,\omega$	$\omega \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\,\omega$
(2) Outside 0,4*L* amidships	$\omega \sqrt{k_m}\,(0{,}95\sqrt{L_R} + 1{,}4) \geq 5{,}0\,\omega$	$\omega \sqrt{k_m}\,(0{,}95\sqrt{L_R} + 1{,}4) \geq 5{,}0\,\omega$	$\omega \sqrt{k_m}\,(0{,}95\sqrt{L_R} + 1{,}4) \geq 5{,}0\,\omega$
Floors and side girders	$\omega \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\,\omega$	$\omega \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\,\omega$	$\omega \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\,\omega$
Inner bottom plating	$\omega \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}3) \geq 3{,}5\,\omega$	$\omega \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}3) \geq 3{,}5\,\omega$	$\omega \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}3) \geq 3{,}5\,\omega$
Bulkheads			
Watertight bulkhead plating	$\omega \sqrt{k_m}\,(0{,}43\sqrt{L_R} + 1{,}2) \geq 3{,}0\,\omega$	$\omega \sqrt{k_m}\,(0{,}43\sqrt{L_R} + 1{,}2) \geq 3{,}0\,\omega$	$\omega \sqrt{k_m}\,(0{,}43\sqrt{L_R} + 1{,}2) \geq 3{,}0\,\omega$
Deep tank bulkhead plating	$\omega \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$	$\omega \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$	$\omega \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$
Deck plating and stiffeners			
Strength/Main deck plating	$\omega \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$	$\omega \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$	$\omega \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\,\omega$
Lower deck/Inside deckhouse	$\omega \sqrt{k_m}\,(0{,}3\sqrt{L_R} + 1{,}3) \geq 3{,}0\,\omega$	$\omega \sqrt{k_m}\,(0{,}3\sqrt{L_R} + 1{,}3) \geq 3{,}0\,\omega$	$\omega \sqrt{k_m}\,(0{,}3\sqrt{L_R} + 1{,}3) \geq 3{,}0\,\omega$
Superstructures and deckhouses			
Superstructure side plating	$\omega \sqrt{k_m}\,(0{,}4\sqrt{L_R} + 1{,}1) \geq 3{,}0\,\omega$	$\omega \sqrt{k_m}\,(0{,}4\sqrt{L_R} + 1{,}1) \geq 3{,}0\,\omega$	$\omega \sqrt{k_m}\,(0{,}4\sqrt{L_R} + 1{,}1) \geq 3{,}0\,\omega$
Deckhouse front 1st tier	$\omega \sqrt{k_m}\,(0{,}62\sqrt{L_R} + 1{,}8) \geq 3{,}5\,\omega$	$\omega \sqrt{k_m}\,(0{,}62\sqrt{L_R} + 1{,}8) \geq 3{,}5\,\omega$	$\omega \sqrt{k_m}\,(0{,}62\sqrt{L_R} + 1{,}8) \geq 3{,}5\,\omega$
Deckhouse front upper tiers	$\omega \sqrt{k_m}\,(0{,}55\sqrt{L_R} + 1{,}5) \geq 3{,}0\,\omega$	$\omega \sqrt{k_m}\,(0{,}55\sqrt{L_R} + 1{,}5) \geq 3{,}0\,\omega$	$\omega \sqrt{k_m}\,(0{,}55\sqrt{L_R} + 1{,}5) \geq 3{,}0\,\omega$
Deckhouse aft	$\omega \sqrt{k_m}\,(0{,}25\sqrt{L_R} + 0{,}7) \geq 2{,}5\,\omega$	$\omega \sqrt{k_m}\,(0{,}25\sqrt{L_R} + 0{,}7) \geq 2{,}5\,\omega$	$\omega \sqrt{k_m}\,(0{,}25\sqrt{L_R} + 0{,}7) \geq 2{,}5\,\omega$
Pillars			
Wall thickness of tubular pillars	$\omega \sqrt{k_m}\,0{,}07 d_p$	$\omega \sqrt{k_m}\,0{,}07 d_p$	$\omega \sqrt{k_m}\,0{,}07 d_p$
Wall thickness of rectangular pillars	$\omega \sqrt{k_m}\,0{,}07 b_p$	$\omega \sqrt{k_m}\,0{,}07 b_p$	$\omega \sqrt{k_m}\,0{,}07 b_p$

Symbols

ω = service type factor as determined from Table 4.2.2
k_m = $385/(\sigma_A + \sigma_u)$
σ_A = specified minimum yield stress or 0,2% proof stress of the alloy in unwelded condition, in N/mm^2
σ_u = specified minimum ultimate tensile strength of the alloy in unwelded condition, in N/mm^2
b_p = minimum breadth of cross section of hollow rectangle pillar, in mm
d_p = outside diameter of tubular pillar, in mm
L_R = as defined in 1.5.1

Table 4.2.2 Service type correction factors (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,0
Patrol	1,0
Pilot	1,1
Yacht	1,0
Workboat MFV	1,2

■ *Section 3* Shell envelope plating

3.1 General

3.1.1 Unless otherwise specified within this Section, the scantlings and arrangements for shell envelope plating are to be determined in accordance with the procedures described in, or as required by, Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in Section 2.

3.2 Keel plates

3.2.1 The breadth, b_k, and thickness, t_k, of plate keels are not to be taken as less than:

$$b_k = 5{,}0 L_R + 250 \text{ mm}$$

$$t_k = \sqrt{k_a}\ 1{,}85 L_R^{0{,}45} \text{ mm}$$

where

L_R and k_a are as defined in 1.5.1.

3.2.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of plate keels are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by Ch 3,3.3.1 for the stem.

3.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

3.3 Bottom outboard

3.3.1 The thickness of the bottom outboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.3.2 For all craft types, the minimum bottom outboard shell thickness requirement given in Section 2 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.4 Bottom inboard

3.4.1 The thickness of the bottom inboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types, the minimum bottom inboard shell thickness requirement given in Section 2 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.5 Side outboard

3.5.1 The thickness of the side outboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.6 Side inboard

3.6.1 The thickness of the side inboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.7 Wet-deck

3.7.1 The thickness of the wet-deck plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.7.2 Additionally, the thickness of the wet-deck plating is in no case to be less than the thickness of the side inboard shell plating determined from 3.6.

3.7.3 The wet-deck plating on the underside of the cross-deck structure may require to be additionally protected, particularly where the air gap is small and there is a high risk of localised impact due to collision with floating debris, ice, etc., in the service area. In such cases the sheathing requirements given in Ch 3,2.4 are to be complied with.

3.8 Transom

3.8.1 The scantlings and arrangements of the stern or transom are to be not less than that required for the adjacent bottom inboard or side outboard structure as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.9 Haunch reinforcement (SWATH)

3.9.1 For craft above 40 m in Rule length, L_R, the stresses in the haunch area are to be derived using a two dimensional fine mesh finite element analysis. The model is to extend horizontally into the box structure and vertically into the strut structure. All discontinuities and cut-outs are to be modelled in order to determine shear stresses at critical locations and stresses for the determination of fatigue strength.

3.9.2 Due consideration is to be given to shear lag when determining the effective breadth of the attached plating.

3.10 Lower hull (SWATH)

3.10.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the thickness of the lower hull shell plating may be derived from an established method for shell analysis or recognised standard for pressure vessels using the design pressure loading from Pt 5, Ch 4,3.1. Other loads considered significant for the scantling determination are to be taken into account. Modes of failure to be considered are buckling, frame collapse, inter-frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations is to be submitted for consideration.

3.11 Novel features

3.11.1 Where the Rules do not specifically define the requirements for plating elements with novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

■ *Section 4* Shell envelope framing

4.1 General

4.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for shell envelope framing are to be determined in accordance with the procedures described in, or as required by, Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

4.1.2 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 Bottom outboard longitudinal stiffeners

4.2.1 Bottom outboard longitudinal stiffeners are to be supported by transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom outboard longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is proposed to terminate the bottom outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, all longitudinals are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.3 Bottom outboard longitudinal primary stiffeners

4.3.1 Bottom outboard longitudinal primary stiffeners are to be supported by deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.3.2 Bottom outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.4 Bottom outboard transverse stiffeners

4.4.1 Bottom outboard transverse stiffeners are defined as local stiffening members which support the bottom shell and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.5 Bottom outboard transverse frames

4.5.1 Bottom outboard transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.6 Bottom outboard transverse web frames

4.6.1 Bottom outboard transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is proposed to terminate the web frames in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.7 Bottom inboard longitudinal stiffeners

4.7.1 The scantlings and arrangements for bottom inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.2 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.8 Bottom inboard longitudinal primary stiffeners

4.8.1 The scantlings and arrangements for bottom inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.3 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.9 Bottom inboard transverse stiffeners

4.9.1 The scantlings and arrangements for bottom inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.4 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.10 Bottom inboard transverse frames

4.10.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.5 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.11 Bottom inboard transverse web frames

4.11.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.6 using the bottom inboard stiffening design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.12 Side outboard longitudinal stiffeners

4.12.1 The side outboard longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.12.2 Side outboard longitudinals are to be continuous through the supporting structures.

4.12.3 Where it is impracticable to comply with the requirements of 4.12.2, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.12.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.13 Side outboard longitudinal primary stiffeners

4.13.1 Side outboard longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.13.2 Side outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.13.3 Where it is impracticable to comply with the requirements of 4.13.2, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.13.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.14 Side outboard transverse stiffeners

4.14.1 Side outboard transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

4.14.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.15 Side outboard transverse frames

4.15.1 Side outboard transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.15.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.16 Side outboard transverse web frames

4.16.1 Side outboard transverse web frames are defined as primary stiffening members which support side shell longitudinals. They are to be continuous and substantially bracketed at their head and heel connections to deck beams and bottom web frames respectively.

4.16.2 Where it is impracticable to comply with the requirements of 4.16.1, or where it is proposed to terminate the side outboard longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.16.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.17 Side inboard longitudinal stiffeners

4.17.1 The scantlings and arrangements for side inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.12 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.18 Side inboard longitudinal primary stiffeners

4.18.1 The scantlings and arrangements for side inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.13 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.19 Side inboard transverse stiffeners

4.19.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.14 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.20 Side inboard transverse frames

4.20.1 The scantlings and arrangements for side inboard transverse frames are to be determined in accordance with the procedures described in 4.15 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.21 Side inboard transverse web frames

4.21.1 The scantlings and arrangements for side inboard transverse web frames are to be determined in accordance with the procedures described in 4.16 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.22 Wet-deck longitudinal stiffeners

4.22.1 The wet-deck longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.22.2 Wet-deck longitudinals are to be continuous through the supporting structures.

4.22.3 Where it is impracticable to comply with the requirements of 4.22.2, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.22.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.22.5 In no case are the scantlings and arrangements for the wet-deck longitudinal stiffeners to be taken as less than those required for the side inboard longitudinal stiffeners detailed in 4.17.

4.23 Wet-deck longitudinal primary stiffeners

4.23.1 Wet-deck longitudinal primary stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.23.2 Wet-deck longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.23.3 Where it is impracticable to comply with the requirements of 4.23.2, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.23.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.23.5 In no case are the scantlings and arrangements for the wet-deck longitudinal primary stiffeners to be taken as less than those required for the side inboard longitudinal primary stiffeners detailed in 4.18.

4.23.6 Additionally the requirements of Chapter 6 relating to global strength are to be complied with.

4.24 Wet-deck transverse stiffeners

4.24.1 Wet-deck transverse stiffeners are defined as local stiffening members supporting the wet-deck and may be continuous or intercostal.

4.24.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.24.3 In no case are the scantlings and arrangements for the wet-deck transverse stiffeners to be taken as less than those required for the side inboard transverse stiffeners detailed in 4.19.

4.25 Wet-deck transverse frames

4.25.1 Wet-deck transverse frames are defined as stiffening members which support the wet-deck. They are to be effectively continuous and bracketed at their end connections to side frames.

4.25.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.25.3 In no case are the scantlings and arrangements for the wet-deck transverse frames to be taken as less than those required for the side inboard transverse frames detailed in 4.20.

4.26 Wet-deck transverse web frames

4.26.1 Wet-deck transverse web frames are defined as primary stiffening members which support wet-deck longitudinals. They are to be continuous and substantially bracketed at their end connections to side transverse web frames.

4.26.2 Where it is impracticable to comply with the requirements of 4.26.1, or where it is proposed to terminate the wet-deck longitudinals in way of the bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.26.4 In no case are the scantlings and arrangements for the wet-deck transverse web frames to be taken as less than those required for the side inboard transverse web frames detailed in 4.21.

4.26.5 Primary transverse web frames that link the strength deck to the wet-deck structure and which carry the transverse global loading are additionally to comply with Ch 6,3.4.

4.26.6 Particular care is to be taken to ensure that the continuity of transverse structural strength is maintained. All primary transverse members are to be continuous through the inboard side structure and integrated into transverse bulkheads or other primary structure within each hull (*see* Fig. 4.4.1). In the case of trimaran type craft the primary transverse members are to be continuous through the centre hull. Additionally the side inboard shell plating in way of the intersection is to be increased locally by not less than 50 per cent.

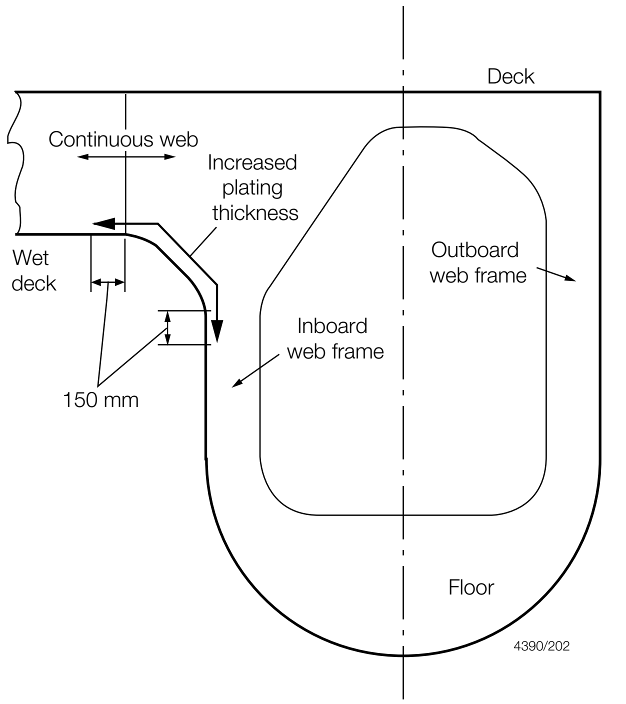


Fig. 4.4.1
End connection details, wet-deck structure

4.27 Lower hull (SWATH)

4.27.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the scantlings of the lower hull shell stiffening may be derived from an established method for stiffening analysis or recognised standard for pressure vessels using the design loading from Pt 5, Ch 4,3.1 Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations is to be submitted for consideration.

4.28 Scantlings of end brackets

4.28.1 The scantlings of end brackets in way of transverse web frames/crossdeck primary structure which carry transverse global loading, are to be as large as practicable and be additionally reinforced as necessary. The webs of deep brackets are to be stiffened as necessary to resist buckling, *see also* Ch 6,3.5.

■ *Section 5*
Single bottom structure and appendages

5.1 General

5.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for single bottom structure and appendages are to be determined in accordance with the procedures described in, or as required by, Ch 3,5 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

5.1.2 The thickness of single bottom structural members is in no case to be less than the appropriate minimum requirement given in Section 2.

5.2 Keel

5.2.1 The scantlings and arrangements of plate keels are to be in accordance with 3.2.

5.2.2 Where fitted, the cross-sectional area, A_{bk}, and thickness, t_{bk}, of bar keels should not, in general, be taken as less than:

$$A_{bk} = k_a (1{,}85 L_R + 2) \text{ cm}^2$$
$$t_{bk} = \sqrt{k_a} (0{,}7 L_R + 8{,}25) \text{ mm}$$

where
L_R and k_a are as defined in 1.5.1.

5.3 Centre girder

5.3.1 Centreline girders are to be fitted throughout the length of each hull and are generally to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders may be formed with intercostal or continuous plate webs. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement are to be provided to maintain the continuity of structural strength.

5.3.3 The web depth of the centre girder is, in general, to be equal to the depth of the floors at the centreline as specified in 5.5.3.

5.3.4 The web thickness, t_w, of the centre girder is to be taken as not less than:

$$t_w = \sqrt{k_a}\left(\sqrt{1{,}9L_R} + 1{,}3\right) \text{ mm}$$

where

k_a and L_R are as defined in 1.5.1.

5.3.5 The face flat area, A_f, of the centre girder is to be not less than:

$$A_f = 0{,}42 k_a L_R \text{ cm}^2$$

where

k_a and L_R are as defined in 1.5.1.

5.3.6 The geometric section properties of the centre girder are to be in accordance with Ch 3,1.18.

5.3.7 The face flat area of the centre girder outside $0{,}5L_R$ may be 80 per cent of the value given in 5.3.5.

5.3.8 The face flat thickness, t_w, is to be not less than the thickness of the web.

5.3.9 The ratio of the width to thickness of the face flat is to be not less than eight but is not to exceed 16.

5.3.10 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 4,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 2 m. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to be scarfed into the bottom structure forward and aft of the support at which they terminate, i.e. terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The web thickness, t_w, of side girders is to be taken as not less than:

$$t_w = \sqrt{0{,}83 k_a L_R} \text{ mm}$$

where

k_a and L_R are as defined in 1.5.1.

5.4.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in 5.5.6 and 5.5.7.

5.4.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

5.4.5 Watertight side girders, and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deeptanks as detailed in Ch 3,7.2 and Ch 3,7.4 respectively.

5.4.6 In the engine room, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.5 Floors general

5.5.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.5.2 In longitudinally framed craft, floors are, in general, to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.5.3 The overall web depth, d_w, of floors at the centre-line, is not to be taken as less than:

$$d_w = 6{,}2L_R + 50 \text{ mm}$$

where

L_R is as defined in 1.5.1.

5.5.4 The web thickness of plate floors, t_w, is to be in accordance with Ch 3,1.18 and not less than:

$$t_w = \sqrt{k_a}\left(\frac{4{,}7d_f}{1000} + 3{,}1\right)\left(\frac{s}{1000} + 0{,}5\right) \text{ mm}$$

where

d_f is determined from 5.5.3 and
k_a and s are as defined in 1.5.1.

5.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.6 The face flat area, A_f, of floors is not to be taken as less than:

$$A_f = k_a \, 0{,}21 L_R \quad \text{cm}^2$$

where

k_a and L_R are defined in 1.5.1.

5.5.7 The face flat thickness, t_f, is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than eight but is not to exceed 16.

5.5.8 Additionally, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

5.5.9 Floors are in general to be continuous from side to side.

5.5.10 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.11 The floors in the aft peak are to extend over and provide efficient support to the stern tube(s) where applicable.

5.5.12 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in Ch 3,7.2 and Ch 3,7.4.

5.6 Floors in machinery space

5.6.1 The web thickness, t_w, of floors in machinery spaces is to be 1 mm greater than that required by 5.5.4.

5.6.2 The depth and mechanical strength properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The face flat area and web thickness of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength (*see also* Ch 3,4.12).

5.7 Forefoot and stem

5.7.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 3.2.

5.7.2 The forefoot and stem are to be additionally reinforced with floors.

5.7.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than :

$$A_{bs} = 1{,}1 k_a L_R \quad \text{cm}^2$$

where

k_a and L_R are as defined in 1.5.1.

■ *Section 6*

Double bottom structure

6.1 General

6.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for the double bottom structure are to be determined in accordance with the procedures described in, or as required by, Ch 3,6 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

6.1.2 The thickness of double bottom structural members is in no case to be less than the appropriate minimum requirement given in Section 2.

6.2 Keel

6.2.1 The scantlings of plate and bar keels are to comply with the requirements of 5.2.

6.3 Centreline girder

6.3.1 A centreline girder is to be fitted throughout the length of the craft. The web thickness, t_w, is to be not less than that required by:

$$t_w = \sqrt{k_a}\,(0{,}082 L_R + 4{,}1) \text{ mm within } 0{,}4L \text{ amidships}$$

$$= \sqrt{k_a}\,(0{,}082 L_R + 2{,}7) \text{ mm at ends}$$

where

k_a and L_R are as defined in 1.5.

6.3.2 The geometric properties of the girder section are to be in accordance with Ch 3,1.18.

6.3.3 The overall web depth, d_w, of the centre girder is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the floor breadth does not exceed 4,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 4,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 2,0 m.

6.4.3 Side girders, where fitted, are to extend as far forward and aft as practicable and are in general to be scarfed into the bottom structure forward and aft of the supporting bulkheads, deep floors or other primary transverse structure.

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 The geometric properties of the girder section are to be in accordance with Ch 3,1.18.

6.4.7 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness, t_w, of non-watertight plate floor is to be not less than:

$$t = \sqrt{k_a}\ (0{,}41 L_R + 4{,}8) \text{ mm}$$

where

k_a and L_R are as defined in 1.5.

6.5.2 The geometric properties of the floor section are to be in accordance with Ch 3,1.18.

6.5.3 Additionally, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

6.5.4 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.5 In longitudinally framed craft, plate floors are to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings, and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engine room.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.6 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_w$ and a thickness of not less than t_w, where t_w is thickness of the plate floor as calculated in 6.5.1.

6.5.7 In transversely framed craft, plate floors are to be fitted at every frame in the engineroom, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Additional requirements for watertight floors

6.6.1 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in Ch 3,7.2 or Ch 3,7.4 respectively.

■ *Section 7* Bulkheads and deep tanks

7.1 General

7.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for bulkheads and deep tanks are to be determined in accordance with the procedures described in, or as required by Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

7.2 Longitudinal bulkheads within the cross-deck structure

7.2.1 Longitudinal bulkheads are to be fitted within the cross-deck structure to prevent cross flooding and the spread of flame and smoke. The minimum number of such bulkheads is to be two for catamarans and four for trimarans. Quadrimarans and other craft of novel configuration will be specially considered.

7.2.2 The scantlings and arrangements for cross deck longitudinal bulkheads are to be determined in accordance with the procedures described in Ch 3,7.2 and Ch 3,7.3 for bulkheads in mono-hull craft.

7.2.3 In addition the requirements of 7.4 with regard to global strength are to be complied with.

7.3 Transverse bulkheads within the cross-deck structure

7.3.1 The scantlings of cross deck transverse bulkheads are to be determined in accordance with the procedures described in Ch 3,7.2 and Ch 3,7.3 for bulkheads in mono-hull craft.

7.3.2 In addition the requirements of 7.4 in respect of global strength are to be complied with.

7.4 Additional strength required for global loadings

7.4.1 Where transverse bulkheads or deep tank bulkheads within the cross deck structure are to assist in resisting torsional or bending loads between the hulls, then the watertight/deep tank bulkheads may be required to be additionally stiffened and the plating or skin thicknesses may require to be increased. For hull girder strength requirements, *see* Ch 6,3.

7.4.2 Longitudinal bulkheads within the cross deck structure that are to assist in maintaining the longitudinal strength of the vessel are to satisfy both bulkhead/deep tank and longitudinal strength requirements. This may require additional stiffening and increase in plate thickness requirements. For hull girder strength requirements, *see* Ch 6,3.

7.4.3 Where longitudinal or transverse cross deck bulkheads/deep tanks are to carry global loads, detailed calculations are to be submitted.

7.4.4 For longitudinal or transverse cross deck members carrying global loads, consideration is to be given to stiffener arrangement, alignment, and continuity in order to maximise the rigidity and stiffness of the structure, in resisting the torsional/bending loads. Discontinuity of structural bulkheads is to be avoided.

7.5 Access

7.5.1 Access through the cross deck structure may be permitted, provided that the global strength requirements are satisfied. Cut outs through the bulkhead are not to exceed 50 per cent of its depth, *see also* Ch 3,7.18.

7.5.2 Where the cross deck structure acts as a watertight bulkhead pipe or cable runs through, the watertight bulkheads are to be fitted with suitable watertight glands.

7.6 Local reinforcement

7.6.1 Bulkheads forming the cross deck structure are to be suitably strengthened, if necessary, in way of deck girders and where subjected to concentrated loads.

7.7 Integral/deep tanks within the cross-deck structure

7.7.1 Where the cross deck structure forms the boundaries of deep tanks, the scantlings of these boundaries are to satisfy both deep tank and global strength requirements. For general and structural requirements for deep tanks, *see* Ch 3,7. For global considerations of strength, *see* Ch 6,3.

■ *Section 8* Deck structures

8.1 General

8.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for deck structures are to be determined in accordance with the procedures described in, or as required by, Ch 3,8 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

8.2 Arrangements

8.2.1 Design loads to be applied for cross-deck scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 5.

8.2.2 For craft up to 50 m in Rule length, L_R, where the cross-deck is formed by transverse primary stiffeners or bulkheads, and subjected to global transverse loads in accordance with 8.2.1 the scantling requirements to satisfy the global loading condition are given in Ch 6,3.5.

8.2.3 Superstructures fitted on the cross-deck structures, on craft up to 50 m in Rule length, L_R, will, in general, be considered as non-load carrying and are not to be included in the strength of the cross-deck. For designs where the superstructure is designed to absorb global loads, the requirements are given in Ch 6,3.2.

8.2.4 For craft more than 50 m in Rule length, L_R, global analysis is required to determine the response of the deck and superstructure as a system. Deck scantlings may then be derived for compliance with the requirements of Ch 6,3.

8.3 Cross-deck plating

8.3.1 The thickness of the cross-deck plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.3.2 The thickness of the cross-deck plating is in no case to be less than the appropriate minimum requirement given in Section 2.

8.3.3 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck, *see also* Part 4.

8.3.4 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.3.5 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* Ch 3,2.4.

8.4 Cross-deck stiffening

8.4.1 The Rule requirements for section modulus, inertia and web area for the cross-deck primary stiffeners are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

8.4.2 The Rule requirements for section modulus, inertia and web area of the strength/weather deck secondary stiffening are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.4.3 The geometric properties of stiffener sections are to be in accordance with Ch 3,1.18.

8.4.4 For cases where there may be excessive rotations or deflections at supports or where the lateral pressure distribution is non-uniform, the above scantlings may require increasing appropriately.

8.4.5 Where stiffeners are subject to concentrated loads such as pillars, the concentrated loads are to be superimposed on the lateral pressure and strength calculations carried out to demonstrate compliance with the deflection and stress criteria given in Ch 7,2 and Ch 7,3.

8.4.6 Where stiffening members support plating of the extruded plank type, or the floating frame system is used, the plating is not to be included in the scantling derivation of the supporting structure.

8.4.7 Openings in the cross-deck for hatches, etc., are to comply with the requirements of Ch 3,8.11.

8.5 Novel features

8.5.1 Where the cross-deck structure is of unusual design, form or proportions, the scantlings are to be determined by direct calculation and a copy is to be submitted for consideration.

■ *Section 9* Superstructures, deckhouses, pillars and bulwarks

9.1 General

9.1.1 The scantlings and arrangements for superstructures, deckhouses and bulwarks are to be determined in accordance with the procedures described in, or as required by, Ch 3,9 for mono-hull craft.

9.1.2 The scantlings and arrangements for pillars and pillar bulkheads are to be determined in accordance with the procedures described in, or as required by, Ch 3,10 for mono-hull craft.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of aluminium construction as defined in Pt 1, Ch 1,1.

1.2 Symbols and definitions

1.2.1 The symbols and definitions used in this Chapter are defined below and in the appropriate Section:

k_a = alloy factor
= $125/\sigma_a$

s = stiffener spacing, in mm

σ_a = 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2.

■ *Section 2* Special features

2.1 Water jet propulsion systems – Construction

2.1.1 The requirements for the construction and installation of water jet units apply irrespective of rated power.

2.1.2 Water jet ducts may be fabricated as an integral part of the hull structure, or as a bolted-in unit. In either case, detailed plans indicating dimensions, scantlings and materials of construction of the following are to be submitted in triplicate:

(a) Arrangement of the system including intended method of attachment to the hull and building-in, geometry of tunnel, shell opening, method of stiffening, reinforcement, etc.
(b) Shaft sealing arrangements.
(c) Details of any shafting support or guide vanes used in the water jet system.
(d) Details and arrangements of inspection ports, their closing appliances and sealing arrangement, etc.
(e) Details and arrangements of protection gratings and their attachments.

2.1.3 When submitting the plans requested in 2.1.2, details of the designers' loadings and their positions of application in the hull are to be submitted. These are to include maximum applied thrust, moments and tunnel pressures for which approval is sought.

2.1.4 All materials used in construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.5 Aluminium alloys are to be of suitable marine grades in accordance with the requirements of Ch 2,2.

2.1.6 Irrespective of the material used, the strength and supporting structure of all tunnels are to be examined by direct calculation procedures which are to be submitted. In no case are the scantlings to be taken as less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

2.1.7 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of the guard are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

2.1.8 The inlet profile of the tunnel is to be so designed as to provide a smooth uptake of water over the range of craft operating trims and avoid significant separation of the flow into the rotating machinery.

2.1.9 Single or multiple water jet unit installations having a total rated power in excess of 500 kW are to be contained within their own watertight compartment. Other arrangements for maintaining watertight integrity may be specially considered depending on the size and installation layout.

2.1.10 For details of machinery requirements, *see* Pt 12, Ch 2.

2.2 Water jet propulsion systems – Installation

2.2.1 Standard units built for 'off the shelf' supply and which include the duct are to be installed strictly in accordance with the manufacturer's instructions, *see also* 2.1.4.

2.2.2 Integral water jet ducts are to be constructed in accordance with the manufacturer's requirements and the relevant plans submitted as required by 2.1.

2.2.3 Where load is transmitted into the transom and/or bottom shell, the thickness of the plating adjacent to the jet unit is to be increased. The increase in thickness is to be not less than 50 per cent of the calculated transom and bottom plating thicknesses respectively or 8 mm, whichever is the greater. Such reinforcement is to extend beyond the surrounding stiffening structure.

2.2.4 For 'bolted in' units, hull receiving rings are to be of a material compatible with the hull. Scantlings of the receiving rings are to be as required by the jet unit manufacturer and suitably edge prepared prior to welding in place. The receiving ring is to be installed using an approved welding procedure. Where a manufacturer's specification is not provided, full details are to be submitted.

2.2.5 Bolt sizes and spacings are to be specified by the manufacturer, and are to be of suitable marine grade, insulated as appropriate and locked by suitable means.

2.2.6 Where studs are proposed for the receiving ring(s), the remaining thickness below the depth of blind tap is to be not less than the bottom shell plating thickness plus 2 mm. Bottoms of all blind taps are to be free of sharp corners.

2.2.7 The use of approved alignment resins may be considered where accurate seating and faying surfaces are required. Details are to be submitted for consideration and approval.

2.2.8 Where a water jet unit forms an integral part of the hull structure, such units are to be installed using an approved weld procedure and in accordance with the manufacturer's instructions. Materials to be welded are to be of compatible specifications.

2.2.9 Water jet units transmitting thrust into the transom structure are to be supported by a system of radial, athwartship and vertical stiffening. Drawings are to be accompanied by a set of detailed structural calculations. Where complex installations are proposed, a finite element model may be submitted in lieu of direct calculations.

2.2.10 Water jet units transmitting thrust to a bottom shell connection or intermediate tunnel connection are to be supported by additional stiffening, the details of which are to be submitted.

2.3 Foil support arrangements

2.3.1 The materials and construction of the lifting surface will be considered on a case by case basis.

2.3.2 The design and performance of the lifting surface is outside the scope of classification. However, when submitting structural plans for the hull connection installation, the designer/Builder is to define:

(a) Operating mode, i.e. fully submerged or surface piercing.
(b) Maximum operational speed for which approval is sought.
(c) Maximum, direct, bending, shear and torque loads generated by the foil at the point of attachment(s).
(d) The type of profile or section used, e.g. N.A.C.A.
(e) Supply of lift/drag profile.
(f) If the foil is fixed, movable or retractable.
(g) If the foil is fitted with control surfaces.
(h) If the vertical leg(s) act as a rudder(s).
(j) If shaft liners are carried to the foils at which support arrangements are provided.
(k) If water intakes/scoops are fitted.
(l) If propulsion units are fitted.

2.3.3 The scantlings and arrangements of foils and their supporting structure will require to be specially considered in the following cases where:

(a) Propulsion units are incorporated within the foil.
(b) Foils carry shaft support arrangements.
(c) The foils are of novel design.

2.3.4 Where fully submerged foils are 'built-in' to the hull, the attachment area is to be contained within a watertight compartment and the structural arrangements of 2.4 are to be complied with as appropriate.

2.3.5 Where foils are to be bolted to the structural foundation calculations are to be submitted to demonstrate that the effect of loading arising from high speed impact, grounding, fouling, etc., is limited to failure of the bolted connection. In all cases the structural and watertight integrity of the craft is to be maintained.

2.3.6 Attachment points of foils are to be contained within a watertight compartment.

2.3.7 Foils attached by riveted means are in addition to comply with Ch 2,4.26.

2.3.8 Bow fairing doors fitted on forward retracting bow foils are to be weathertight and comply with Pt 3, Ch 4.

2.3.9 Aft bulkheads of bow foil compartments are to comply with the requirements for collision bulkheads as detailed in Ch 3,7.7.

2.3.10 Hydraulically operated retracting systems are to be equipped with low pressure and are to include a manual system of operation in the event of system failure.

2.3.11 A mechanical locking system is to be provided on retracting systems when the system is in both the operational and 'stowed' conditions.

2.4 Surface drive mountings

2.4.1 Transoms through which surface drive systems pass and which are required to carry thrust, significant weight, torque, moment, etc., are to be adequately reinforced.

2.4.2 The thickness of transom plating in way is to be not less than 1,5 times the thickness of the adjacent plating or as advised by the drive manufacturer, whichever is the greater.

2.4.3 Steering rams are to be mounted on suitably reinforced areas of plating supported by additional internal stiffening, details of which are to be submitted for consideration.

2.5 Sea inlet scoops

2.5.1 Sea inlet scoops may be integral with or an appendage to the hull.

2.5.2 Scoops are to be suitably positioned to minimise ventilation.

2.5.3 Suitable protective arrangements are to be provided to minimise the ingress of debris. The net area through the proposed arrangement is to be not less than twice that of the valves connected to the scoop. Provision is to be made for clearing the scoops by the use of suitable means and proposals are to be submitted.

2.5.4 Scoops are to be contained within a watertight compartment.

2.5.5 The plating thickness in way of integral scoops is to be not less than 1,5 times the thickness of the adjacent shell plating, with additional reinforcement at the leading edge.

2.5.6 For craft navigating in ice, the arrangements will be specially considered on an individual basis.

2.6 Crane support arrangements

2.6.1 Crane pedestals are to be efficiently supported and in general, are to be carried through the deck and satisfactorily scarfed into the surrounding structure. Alternatively, crane pedestals may comprise a foundation, in which case the foundation and its supporting structure are to be of substantial construction. Proposals for other support arrangements will be specially considered.

2.6.2 The pedestal or proposed arrangement is to be designed with respect to the worst possible combinations of loads resulting from the crane self weight, live load, wind and crane accelerations together with those resulting from the craft's heel and trim.

2.6.3 Stowage arrangements are to be taken into account when calculating the loads applied to the pedestal.

2.6.4 When submitting plans for the proposed foundation, the designer is to include design calculations covering the parameters indicated in 2.6.2.

2.6.5 Insert plates are to be incorporated in the deck plating in way of crane foundations. The thickness of the insert plates is to be as required by the designer's calculations but is in no case is to be taken as less than 1,5 times the thickness of the adjacent attached plating.

2.6.6 All inserts are to have well radiused corners and be suitably edge prepared prior to welding. All welding in way is to be double continuous and full penetration where necessary. Tapers are to be not less than three to one.

2.7 Skirt attachment

2.7.1 The design and scantlings of the skirt are outside the scope of classification, however the designers/builders are to submit their proposals in respect of the attachment detail. The following supporting information is to be submitted:

(a) cushion pressure;
(b) calculations demonstrating that the effect of damage to the flexible membrane and/or the retaining section arising from high speed impact, grounding, fouling, etc., will not compromise the structural and watertight integrity of the craft.

2.7.2 The skirt is to be securely attached around its periphery and is to be suitably reinforced by the use of backing plates.

2.7.3 Where the skirt is retained by bolting the retaining bars are to be as long as practicable with a fastener spacing of not more than 50 mm.

2.7.4 Where the design of the skirt is such that the flexible edge is retained by the use of a pre-formed channel, only the bolted hull connection of the preform to the hull structure is considered.

2.8 Trim tab arrangements

2.8.1 The shape, design and scantlings of the trim tabs are outside the scope of classification, however Lloyd's Register (hereinafter referred to as 'LR') is concerned with their attachment to the hull structure.

2.8.2 The designer/Builder is to submit the following:

(a) Detailed calculations indicating the maximum lift force generated by the tab for which acceptance is sought together with the corresponding speed and displacement.
(b) Details and calculations of the hull attachment.
(c) Details and calculations of the local internal reinforcement in way of the attachment.

2.8.3 Bearing materials used are to be of an approved type.

2.8.4 Fully submerged retractable trim tabs will be specially considered on a case by case basis.

2.9 Spray rails

2.9.1 Spray rails may be integrated into the hull structure or added in the form of an appendage on completion of the hull shell.

2.9.2 Where spray rails are integrated, they are to have a plating thickness not less than the adjacent bottom shell and additionally have a section modulus and inertia equivalent to that required for a longitudinal stiffener in the same position.

2.9.3 Where spray rails are added as an appendage, they are to be attached by double continuous welding and are additionally to comply with the strength requirements of 2.9.2.

2.9.4 Spray rails are to be supported by the internal stiffening arrangements and by additional local reinforcement as necessary.

2.9.5 In no case are the toes of spray rails to terminate on unsupported plating.

2.10 Other lifting surfaces

2.10.1 Other lifting surfaces not specifically covered by the Rules will be individually considered on the basis of submitted direct calculations.

2.10.2 Structure or hull shapes above the running waterline designed to generate aerodynamic lift may be individually considered on a case by case basis.

2.10.3 Aerodynamic, hydrodynamic and aero-hydrodynamic stability are outside the scope of classification and are subject to the approval of the National Administration concerned.

2.11 Propeller ducting

2.11.1 Where propellers are fitted within ducts/tunnels the plating thickness in way of the blades is to be increased by 50 per cent.

2.11.2 The tunnel wall in way of the propeller blades is to be additionally stiffened.

2.12 Ride control ducting and installation for Surface Effect Ships (SES)

2.12.1 Ducts penetrating the side inboard shell plating are to comply with the scantling requirements for side inboard structures, over their entire length in the appropriate material.

2.12.2 Ducts penetrating the wet-deck are to comply with the scantling requirements for wet-deck structures over their entire length in the appropriate material.

2.12.3 Open ends of ducts are to be fitted with a suitable protective grille.

2.12.4 The vent assembly, its design, construction and operation are outside the scope of classification and is the responsibility of the ride control system designer.

2.12.5 Details of the installation and securing arrangements of the vent valve assembly into the duct are to be submitted for approval.

■ *Section 3* Vehicle decks

3.1 General

3.1.1 These requirements are applicable to longitudinally or transversely framed craft intended for the carriage of wheeled vehicles, or where wheeled vehicles are to be used for cargo handling.

3.1.2 The deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, the hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.1.3 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Builder. These details are to include axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. The vehicle types and wheel loads for which the vehicle decks, including hatch covers where applicable, have been approved are to be included in the craft's documentation and contained in a notice displayed on each deck. For design purposes, the wheel loading is to be taken as not less than 3,0 kN.

3.1.4 The scantling requirements are based on structural strength and limitations on stress and deflection, with no allowance made for wear and tear. Local reinforcement is to be fitted as necessary, particularly in way of vehicle lanes and passenger routes.

3.1.5 The webs of vehicle deck stiffening members are in no cases to be scalloped.

3.2 Definitions

3.2.1 **Load area.** The load area is defined as the footprint area of an individual wheel or the area enclosing a group of wheels when the distance between footprints is less than the smaller dimension of the individual prints.

3.3 Deck plating

3.3.1 The thickness, t_p, of vehicle deck plating is to be taken as not less than:

$$t_p = \frac{\alpha s}{1370\sqrt{k_a}} \text{ mm}$$

where

P_1 = corrected patch load, in tonnes, obtained from Table 5.3.1
α = thickness coefficient obtained from Fig. 5.3.1
s = secondary stiffener spacing, in mm
β_p = tyre print coefficient used in Fig. 5.3.1
$= \log_{10}\left(\frac{3{,}5 P_1 k_a^2}{s^2} \times 10^7\right)$

s and k_a are as defined in 1.2.

Table 5.3.1 Deck plate thickness calculation

Symbols	Expression	
a, *s*, *u*, and *v* as defined in Fig. 5.3.1 n = tyre correction factor as detailed in Table 5.3.2 P_1 = corrected patch load, in tonnes λ = dynamic magnification factor P_w = load, in tonnes, on the tyre print. For closely spaced wheels the shaded area shown in Fig. 5.3.1 may be taken as the combined print λ = dynamic magnification factor ϕ_1 = patch aspect ratio correction factor ϕ_2 = panel aspect ratio correction factor ϕ_3 = wide patch load factor	$P_1 = \phi_1\ \phi_2\ \phi_3\ \lambda\ P_w$	
	$\phi_1 = \dfrac{2v_1 + 1,1s}{u_1 + 1,1s}$	$v_1 = v$, but $\leq s$ $u_1 = u$, but $\leq a$
	$\phi_2 = 1,0$ $= \dfrac{1}{1,3 - \dfrac{0,3}{s}(a - u)}$ $= 0,77\ \dfrac{a}{u}$	for $u \leq (a - s)$ for $a \geq u > (a - s)$ for $u > a$
	$\phi_3 = 1,0$ $= 0,6\ (s/v) + 0,4$ $= 1,2\ (s/v)$	for $v < s$ for $1,5 > (v/s) > 1,0$ for $(v/s) \geq 1,5$
	$\lambda = 1,25$ for craft operating in G1 $= (1 + 0,35n)$ for craft operating in G2 $= (1 + 0,42n)$ for craft operating in G3 $= (1 + 0,49n)$ for craft operating in G4 $= (1 + 0,56n)$ for craft operating in G5 $= (1 + 0,70n)$ for craft operating in G6 G1, G2, G3, G4, G5 and G6 as defined in Pt 1, Ch 2,3.5.5	

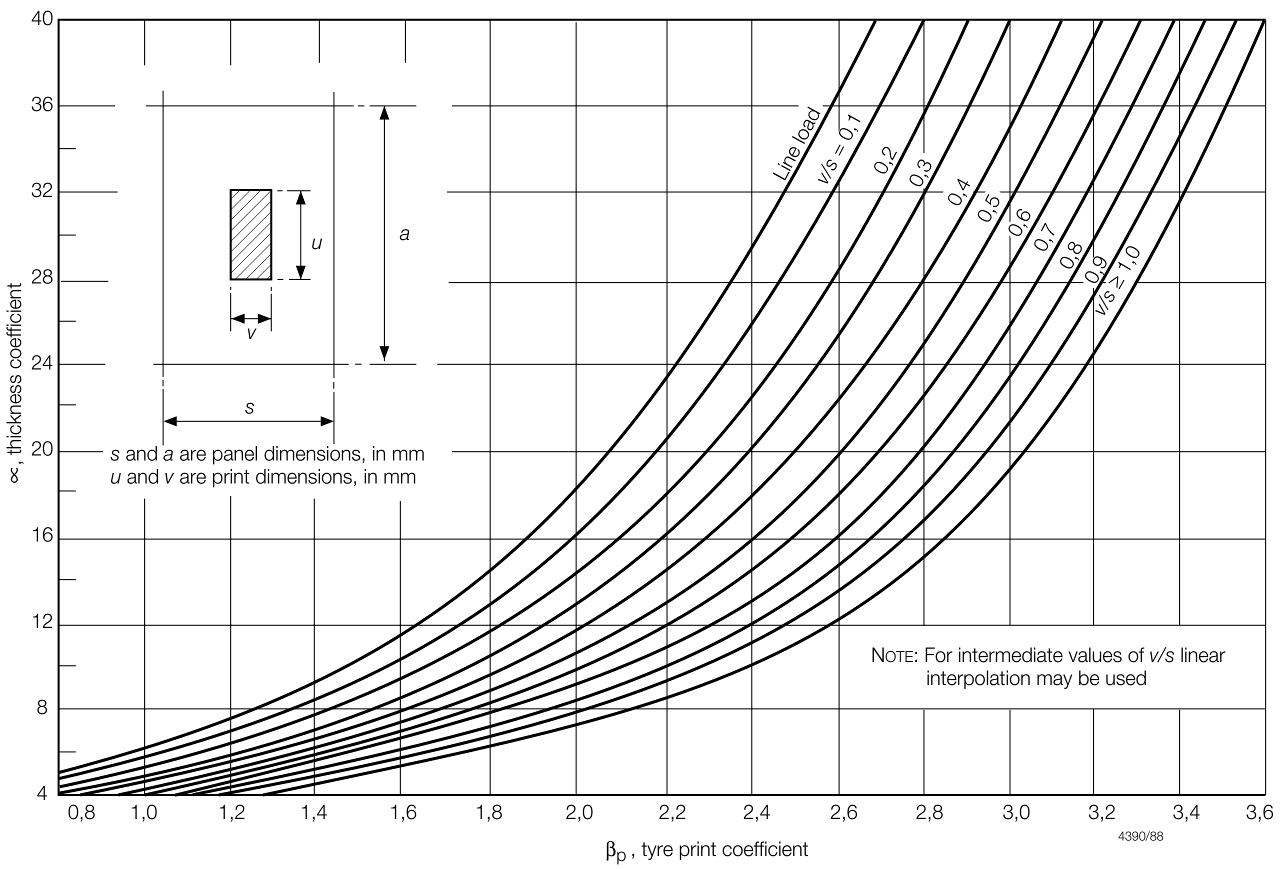


Fig. 5.3.1 Tyre print chart

3.4 Secondary stiffening

3.4.1 The scantlings of vehicle deck stiffeners are to be as required to satisfy the most severe arrangement of print wheel loads in conjunction with the cargo/weather deck design head.

3.4.2 The minimum requirements for section modulus, inertia and web area of vehicle deck secondary stiffeners subject to wheel loading are to be calculated in accordance with Table 5.3.3, *see also* Fig. 5.3.1 and Table 5.3.2.

Table 5.3.2 Tyre correction factor, *n*

Number of wheels in idealised patch	Pneumatic tyres correction factor, n	Solid rubber tyres correction factor, n
1	0,6	0,8
2 or more	0,75	0,9

3.4.3 When two or more load areas are located simultaneously on the same stiffener span, the scantling requirements are to be specially considered on the basis of direct calculation.

3.4.4 Where continuous secondary stiffeners pass through the webs of primary members, they are to be fully collared or lugged in way. The shear stresses at the connections are to be in compliance with Table 7.3.1 in Chapter 7.

3.5 Primary stiffening

3.5.1 The scantlings of vehicle deck primary girders and transverse web frames are to be determined on the basis of direct calculation in association with the limiting permissible stress and deflection criteria contained in Chapter 7.

3.6 Securing arrangements

3.6.1 Details of the connections to the hull of vehicle securing arrangements are to be submitted for approval.

3.6.2 Deck fittings in way of vehicle lanes are to be recessed.

3.6.3 The vehicle deck structure is to be of adequate strength for the upward forces imposed at fixed securing points. Local reinforcement is to be fitted as necessary.

Table 5.3.3 Secondary stiffener requirements

Scantling requirement	Load case $d \le l$	Load case $d > l$
Section modulus (Z) (cm^3)	$Z = \left(\dfrac{P\ k_w (3l^2 - d^2)}{24\ l\ f_\sigma\ \sigma_a}\right) \times 10^3 + Z_{dk}$	$Z = \left(\dfrac{k_w\ P\ l^2}{10\ d\ f_\sigma\ \sigma_a}\right) \times 10^3 + Z_{dk}$
Inertia (I) (cm^4)	$I = \left(\dfrac{f_\delta\ P\ k_w (2l^3 - 2d^2\ l + d^3)}{384\ E\ l}\right) \times 10^5 + I_{dk}$	$I = \left(\dfrac{f_\delta\ k_w\ P\ l^3}{384\ E\ d}\right) \times 10^5 + I_{dk}$
Web area (A_W) (cm^2)	$A_W = \dfrac{10P\ k_w (m^3 - 2m^2 + 2)}{2\ f_\tau\ \tau_a} + A_{dk}$ where $m = d/l$	$A_W = \dfrac{k_w\ P\ l}{2\ d\ f_\tau\ \tau_a} + A_{dk}$

Symbols

P = maximum effective load per wheel or group of wheels, in kN
l = overall secondary stiffener length, in metres
s = stiffener spacing, in metres
d = dimension of load area parallel to stiffener axis, in metres
E = Young's modulus of elasticity of material, in N/mm^2
w = dimension of load area perpendicular to stiffener axis, in metres
k_w = lateral loading factor
= 1 for $w \le s$
= s/w for $w > s$
f_σ = limiting bending stress coefficient taken from Table 7.3.1 in Chapter 7
f_τ = limiting shear stress coefficient taken from Table 7.3.1 in Chapter 7
f_δ = limiting deflection coefficient taken from Table 7.2.1 in Chapter 7
σ_a = 0,2% proof stress of material, in N/mm^2
τ_a = shear stress of the alloy, in N/mm^2
= $\dfrac{\sigma_a}{\sqrt{3}}$
Z_{dk}, I_{dk}, A_{dk} = stiffener requirements for weather/cargo decks to be determined in accordance with Ch 3,8.7 and Ch 3,8.10 using the appropriate design head for weather/cargo. In no case is the head to be taken as less than 2 kN/m^2

3.7 Access

3.7.1 Bow doors are to comply with the requirements of Section 4.

3.7.2 Where access to the vehicle deck is provided by side and stern doors the doors are to have scantlings equivalent to the structure in which they are fitted, *see also* Pt 3, Ch 4,4.

3.7.3 Doors providing pedestrian access between vehicle decks and accommodation spaces are to be gastight, have scantlings equivalent to the surrounding structure and where applicable are to comply with the requirements of Part 17.

3.8 Hatch covers

3.8.1 The scantlings and arrangements of hatches and hatch covers located within vehicle decks are to be not less than that required by the Rules for the supporting structure in which such hatches are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

3.8.2 In no case, however, are the scantlings of plating and stiffeners to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.8.3 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of plating and stiffeners may be determined by direct calculations using a two-dimensional grillage model. A copy of the calculations is to be submitted.

3.9 Heavy and special loads

3.9.1 Where heavy or special loads are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered on the basis of submitted calculations.

3.9.2 Due account is to be taken of the acceleration levels due to craft motion as applicable to particular items of heavy mass such as vehicles, containers, pallets, etc.

3.10 Direct calculations

3.10.1 LR will consider direct calculations for the derivation of scantlings as an alternative to and equivalent to those derived by Rule requirements. The assumptions made and the calculation procedures used are to be submitted for appraisal in accordance with Pt 3, Ch 1,2.

■ *Section 4* Bow doors

4.1 Application

4.1.1 The requirements of this Section are applicable to the arrangement, strength and securing of bow doors, both the visor and the side opening type doors, and inner doors leading to a complete or long forward enclosed superstructure.

4.1.2 Other types of bow door will be specially considered.

4.2 General

4.2.1 The attention of Owners and Builders is drawn to the additional statutory regulations for bow doors that may be imposed by the National Authority.

4.2.2 Bow doors are to be situated above the freeboard deck. A watertight recess in the freeboard deck located forward of the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the freeboard deck.

4.2.3 An inner door is to be fitted. The inner door is to be part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, *see* Pt 3, Ch 2,4. A vehicle ramp may be arranged for this purpose, provided its position complies with Pt 3, Ch 2,4 and the ramp is weathertight over its complete length. In this case the upper part of the ramp higher than 2,3 m above the freeboard deck may extend forward of the limit specified in Pt 3, Ch 2,4. If this is not possible a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

4.2.4 Bow doors are to be fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors. Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

4.2.5 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in 4.2.3.

4.2.6 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in the stowed position.

4.3 Symbols and definitions

4.3.1 The symbols used in this Section are defined as follows:

a_{bv} = vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Fig. 5.4.2

b_{bv} = horizontal distance, in m, from visor pivot to the centroid of the horizontal projected are of the visor door, as shown in Fig. 5.4.2

c_{bv} = horizontal distance, in m, from visor pivot to the centre of gravity of visor mass, as shown in Fig. 5.4.2

h = height of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in metres, whichever is the lesser, as shown in Fig. 5.4.1

k_a = alloy factor
= $125/\sigma_a$

l_d = length of the door at a height $h/2$ above the bottom of the door, in metres, as shown in Fig. 5.4.2

A_s = area stiffener web in cm^2

A_x = area, in m^2, of the transverse vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser, as shown in Fig. 5.4.2

A_y = area, in m^2, of the longitudinal vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser

A_z = area of the horizontal projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in m^2, whichever is the lesser, as shown in Fig. 5.4.2

Q_{bd} = shear force, in kN, in the stiffener calculated by using uniformly distributed external pressure P_e as given in 4.5.1

W = breadth of the door at a height $h/2$ above the bottom of the door, in metres, as shown in Fig. 5.4.1

W_{bv} = mass of the visor door, in tonnes

σ = bending stress, in N/mm^2

σ_a = material yield stress, in N/mm^2

σ_{eq} = equivalent stress, in N/mm^2
= $\sqrt{\sigma^2 + 3\tau^2}$

τ = shear stress, in N/mm^2.

4.3.2 **Locking device.** A device that locks a securing device in the closed position.

4.3.3 **Securing device.** A device used to keep the door closed by preventing it from rotating about its hinges.

4.3.4 **Side-opening doors.** Side-opening doors are opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the craft. It is anticipated that side-opening doors are arranged in pairs.

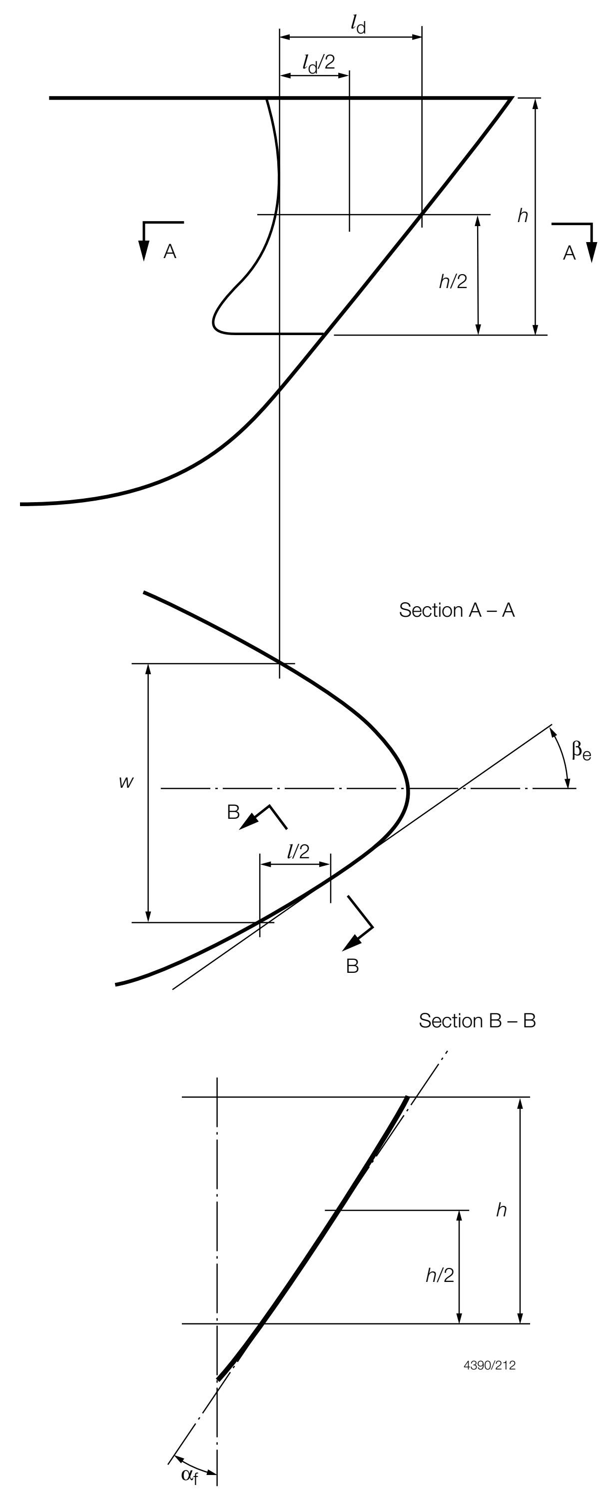


Fig. 5.4.1 Measurement of α_f and β_e

4.3.5 **Supporting device**. A device used to transmit external or internal loads from the door to a securing device and from the securing device to the craft's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the craft's structure.

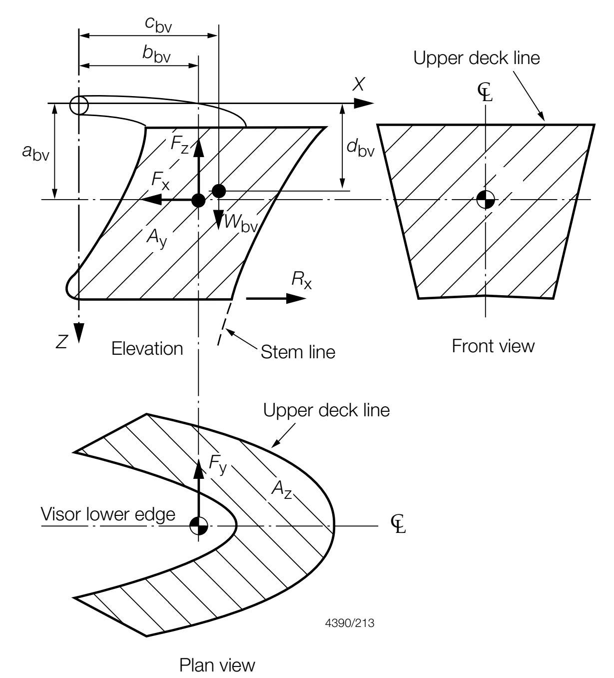


Fig. 5.4.2 Bow visor (upward hinging)

4.3.6 **Visor doors.** Visor doors are opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary structure of the door by longitudinally arranged lifting arms.

4.4 Strength criteria

4.4.1 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be able to withstand the design loads defined in 4.5. The shear, bending and equivalent stresses are not to exceed $43/k_a$ N/mm^2, $64/k_a$ N/mm^2 and $80/k_a$ N/mm^2 respectively.

4.4.2 The buckling strength of primary members is to be verified as being adequate, *see* Ch 7,4.

4.4.3 For metal to metal bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed 80 per cent of the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.

4.4.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of steel bolts not carrying support forces is not to exceed $125/k_s$ N/mm^2.

4.5 Design loads

4.5.1 The design external pressure, P_e, for the determination of scantlings for primary members, securing and supporting devices of bow doors is taken to be not less than the following:

$$P_e = 2{,}75\lambda_G C_H \left(0{,}22 + 0{,}15\tan\alpha_f\right)\left(0{,}4V_{max}\sin\beta_e + 0{,}6L_R^{0{,}5}\right)^2 \quad \text{kN/m}^2$$

where

C_H = $0{,}0125L_R$ for $L_R < 80$ m
= 1,0 for $L_R \geq 80$ m

L_R = Rule length of craft, in m as defined in Pt 3, Ch 1,6

V_{max} = maximum speed in knots as defined in Pt 1, Ch 2, 2.2.10.

λ_G = Service group factor for mono-hull craft, *see* Pt 1, Ch 2
= 0,5 for Group 1 and 2
= 0,6 for Group 3
= 0,8 for Group 4
= 1,0 for Group 5 and 6
For multi-hull craft, λ_G will be specially considered and may be reduced where the freeboard is significant

α_f = flare angle at the point to be considered, defined as the angle between a vertical line and the tangent to the side shell plating, measured in a vertical plane normal to the horizontal tangent to the shell plating, *see* Fig. 5.4.1

β_e = entry angle at the point to be considered, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane, *see* Fig. 5.4.1.

4.5.2 The design external forces, F_x, F_y and F_z, in kN, for the determination of scantlings of securing and supporting devices of bow doors are taken to be not less than $P_e A_x$, $P_e A_y$ and $P_e A_z$ respectively.

where

P_e is the external pressure, defined in 4.5.1, with the flare angle, α_f, and the entry angle, β_e, measured at the point on the bow door, $l_d/2$ aft of the stem line on the plane $h/2$ above the bottom of the door, as shown in Fig. 5.4.1.
A_x, A_y, A_z and h as defined in 4.3.1.

4.5.3 For bow doors, including bulwark, of unusual form or proportions, the areas used for the determination of the design values of external forces will be specially considered.

4.5.4 For visor doors the closing moment, M_y, under external loads, is to be taken as:

$$M_y = F_x a_{bv} + 10W_{bv} c_{bv} - F_z b_{bv} \quad \text{kNm}$$

where

W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in 4.3.1
F_x and F_z are as defined in 4.5.2.

4.5.5 The lifting arms of a visor and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1,5 kN/m^2 is to be taken.

4.5.6 The design external pressure, in kN/m^2, for the determination of scantlings for primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of 0,45L_R and 10h_2, where h_2 is the distance, in m, from the load point to the top of the cargo space and L_R is as defined in Pt 3, Ch 1,6.2.1.

4.5.7 The design internal pressure for the determination of scantlings for securing devices of inner doors is not to be taken less than 25 kN/m^2.

4.6 Scantlings of bow doors

4.6.1 The strength of bow doors is to be commensurate with that of the surrounding structure.

4.6.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed. For visor doors adequate strength for the opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the craft structure.

4.6.3 The thickness of the bow plating is not to be less than that required for the side shell plating, using bow door stiffener spacing, but in no case less than the minimum required thickness of fore end shell plating.

4.6.4 The section modulus of horizontal or vertical stiffeners is not to be less than that required for end framing. Consideration is to be given, where necessary, to differences in fixity between craft's frames and bow doors stiffeners.

4.6.5 The stiffener webs are to have a net sectional area A_s, not less than:

$$A_s = \frac{12{,}5 Q_{bd}}{\sigma_a} \text{ cm}^2$$

where

A_s, Q_{bd} and σ_a are as defined in 4.3.1.

4.6.6 The bow door secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

4.6.7 The primary members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

4.6.8 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in 4.5.1 and permissible stresses given in 4.4.2.

4.7 Scantlings of inner doors

4.7.1 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in and permissible stresses given in 4.4.1. In general, formulae for simple beam theory may be applied.

4.7.2 Where inner doors also serve as a vehicle ramps, the scantlings are not to be less than those required for vehicle decks.

4.7.3 The distribution of the forces acting on the securing and supporting devices is, in general, to be supported by direct calculations taking into account the flexibility of the structure and actual position and stiffness of the supports.

4.8 Securing and supporting of bow doors

4.8.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is, in general, not to exceed 3 mm. A means is to be provided for mechanically fixing the door in the open position.

4.8.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide load compression of the packing material are, in general, not to be included in the calculations called for in 4.8.8. The number of securing and supporting devices are, in general, to be the minimum practical whilst taking into account the requirements for redundant provision given in 4.8.9 and 4.8.10 and the available space for adequate support in the hull structure.

4.8.3 For opening outwards visor doors, the pivot arrangement is generally to be such that the visor is self closing under external loads, that is $M_y > 0$. Moreover, the closing moment, M_y, as given in 4.5.4 is to be not less than:

$$M_{ya} = 10 W_{bv} c_{bv} + 0{,}1(a_{bv}^2 + b_{bv}^2)^{0,5} (F_x^2 + F_z^2)^{0,5}$$

where

W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in 4.3.1
F_x and F_z are as defined in 4.5.2.

4.8.4 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in 4.4.1.

4.8.5 For **visor doors** the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door.

Case 1 F_x and F_z.
Case 2 0,7F_y acting on each side separately together with 0,7F_x and 0,7F_z

where

F_x, F_y and F_z are to be determined as indicated in 4.5.2 and applied at the centroid of projected areas.

4.8.6 For **side-opening doors** the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

Case 1 F_x , F_y and F_z acting on both doors.

Case 2 $0,7F_x$ and $0,7F_z$ acting on both doors and $0,7F_y$ acting on each door separately.

where

F_x, F_y and F_z are to be determined as indicated in 4.5.2 and applied at the centroid of projected areas.

4.8.7 The support forces as determined according to 4.8.5 and 4.8.6 are to generally give rise to a zero moment about the transverse axis through the centroid of the area A_x. For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be of the forward direction.

4.8.8 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

4.8.9 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20 per cent the permissible stresses as given in 4.4.1.

4.8.10 For **visor doors**, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in 4.4.1. The opening moment, M_o, to be balanced by this reaction force, is not to be taken less than:

$$M_o = 10W_{bv}\, d_{bv} + 5A_x\, a_{bv} \text{ kNm}$$

where

W_{bv}, A_x, d_{bv} and a_{bv} are as defined in 4.3.1.

4.8.11 For **visor doors**, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design force (F_z – $10W_{bv}$), in kN, within the permissible stresses given in 4.4.1.

4.8.12 All load transmitting elements in the design load path, from door through securing and supporting devices into the craft structure, including welded connections, are to be the same strength.

4.8.13 For **side-opening doors**, thrust bearing has to be provided in way of girder ends at the closing of the two leaves to prevent one leaf to shift towards the other one under effect of unsymmetrical pressure, *see* Fig. 5.4.3. Each part of the thrust bearing has to be kept secured on the other part by means of securing devices. Any other arrangements serving the same purpose are to be submitted for appraisal.

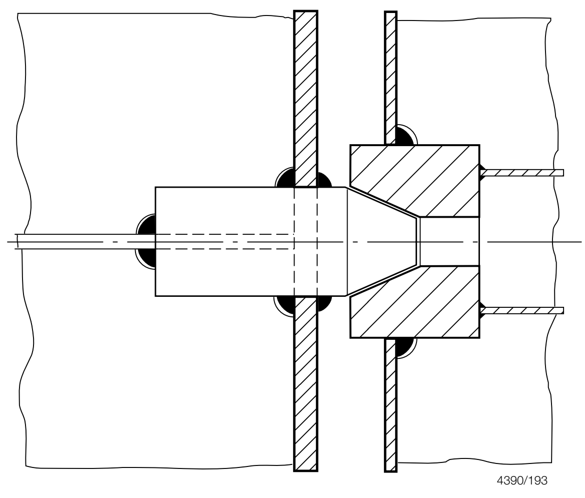


Fig. 5.4.3 Typical thrust bearing

4.9 Securing and locking arrangement

4.9.1 Securing devices are to be simple to operate and easily accessible. Securing devices are to be equipped with mechanical locking arrangement (self locking or separate arrangement), or be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

4.9.2 Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

(a) the closing and opening of the doors; and

(b) associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorised persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

4.9.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in the closed position so that in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in the closed position.

4.9.4 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. The indicator lights are to be provided with a permanent power supply, further, arrangements are to be such that it is not possible to turn off these lights in service.

4.9.5 The indicator system is to be designed on the fail-safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors. The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.

4.9.6 The indication panel on the navigation bridge is to be equipped with a mode selection function 'harbour/sea voyage', so arranged that audible alarm is given if the craft leaves harbour with the bow door or inner door not closed and with any of the securing devices not in the correct position.

4.9.7 A water leakage detection system with audible alarm and television surveillance are to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

4.9.8 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room. The system is to be able to monitor the position of doors and a sufficient number of their securing devices. Special consideration is to be given for lighting and contrasting colour of objects under surveillance.

4.9.9 A drainage system is to be arranged in the area between bow door and ramp, as well as in the area between the ramp and inner door where fitted. The system is to be equipped with an audible alarm function to the navigation bridge for water level in these areas exceeding 0,5 m above the car deck level.

4.10 Operating and Maintenance Manual

4.10.1 An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and contain necessary information on:

(a) main particulars and design drawings,
(b) service conditions, e.g. service area restrictions, acceptable clearances for supports,
(c) maintenance and function testing,
(d) register of inspections and repairs.

This manual is to be submitted for approval.

4.10.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

■ *Section 5*
Movable decks

5.1 Classification

5.1.1 Movable decks other than those described in 5.1.2 are not a classification item, although consideration must be given to associated supporting structure. Where movable decks are fitted, it is recommended that they be based on the requirements of this Section.

5.1.2 At the Owner's or Builder's request, however, movable decks will be included as a classification item, and the class notation **Movable decks** will be entered in the *Register Book*. In such cases, all movable decks on board the ship are to comply with the requirements of this Section.

5.2 Arrangements and designs

5.2.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

5.2.2 Positive means of control are to be provided to secure decks in the lowered position.

5.2.3 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

5.2.4 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

5.2.5 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc., are to be submitted for consideration.

5.3 Loading

5.3.1 Details of the deck loading resulting from the proposed stowage arrangements of vehicles are to be supplied by the Shipbuilder. These details are to include the axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. For design purposes the wheel loading is to be taken as not less than 3,0 kN, *see* Section 3.

5.3.2 Where it is proposed also to use the decks for general cargo, the design loadings are to be submitted for consideration.

5.4 Scantling requirements

5.4.1 The scantlings and arrangements of removable decks are to be not less than those required by the Rules for the supporting structure in which the movable decks are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

5.5 Deflection

5.5.1 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during loading or unloading operations.

■ *Section 6* Helicopter landing areas

6.1 General

6.1.1 The landing area may be located on an appropriate area of the weather deck or on a platform specifically designed for this purpose and permanently connected to the craft structure.

6.1.2 The structure is to be designed to accommodate the largest helicopter type which it is intended to use. In general, the diameter of the landing area is to be not less than 1,25 times the rotor diameter.

6.1.3 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the craft.

6.1.4 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of helicopters to be used are also to be indicated. Details of the helicopter types to be used are to be included in the craft's documentation, and be contained in a notice displayed on the helicopter landing deck.

6.1.5 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

6.1.6 The requirements for fire protection, detection and extinction for yachts are to comply with Part 17. The requirements for other types of craft are outside the scope of classification and are therefore to comply with the requirements for the National Authority. Special consideration is to be given to the insulation standard if the space below the helicopter deck is a high fire-risk space.

6.2 Arrangements

6.2.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the helicopter, and is to be approached by a clear landing and take-off sector complying in extent with the applicable regulations.

6.2.2 The landing area is to be free of any projections above the level of the deck. Projections in the zone surrounding the landing area are to be kept below the heights permitted by the Regulations.

6.2.3 Suitable arrangements are to be made to minimize the risk of personnel or machinery sliding off the landing area. A non-slip surface and anchoring devices, and in the case of independent platforms, safety nets, are to be provided.

6.2.4 Arrangements are to be made for drainage of the platform, including drainage of spilt fuel.

6.2.5 Details of arrangements for securing the helicopter to the deck are to be submitted for approval.

6.3 Landing area plating

6.3.1 The deck plate thickness, t_p, within the landing area is to be not less than:

$$t_p = \frac{\alpha s}{1370\sqrt{k_a}}$$

α = thickness coefficient obtained from Fig. 5.3.1
β_p = tyre print coefficient used in Fig. 5.3.1
$= \log_{10}\left(\frac{3,5\, P_1\, k_a^2}{s^2} \times 10^7\right)$

where
s and k_a are as defined in 1.2.

The plating is to be designed for the emergency landing case taking:

$P_1 = 2,5\phi_1\, \phi_2\, \phi_3\, f\, \gamma\, P_w$ tonnes

where ϕ_1, ϕ_2, ϕ_3 are to be determined from Table 5.3.1
f = 1,15 for landing decks over manned spaces, e.g. deckhouses, bridges, control rooms, etc.
= 1,0 elsewhere
P_h = the maximum all up weight of the helicopter, in tonnes
P_w = landing load, on the tyre print, in tonnes
P_w is to be taken as P_h divided equally between the two main undercarriages (for helicopters with single main rotor)
γ = a location factor given in Table 5.6.1
k_a is as defined in 1.2.
The tyre print dimensions specified by the manufacturer are to be used for the calculation. Where these are unknown it may be assumed that the print area is 300 x 300 mm and this assumption is to be indicated on the submitted plan.

6.3.2 For helicopters fitted with landing gear consisting of skids, the print dimensions specified by the manufacturer are to be used. Where these are unknown it may be assumed that the print consists of a 300 mm line load at each end of each skid, when applying Fig. 5.3.1.

Table 5.6.1 Location factor, γ

Location	γ
On decks forming part of the hull girder: (a) within 0,4L_R amidships (b) at the F.P. or A.P.	 0,71 Values for intermediate locations are to be 0,6 determined by interpolation
Elsewhere	0,6

6.4 Deck stiffening

6.4.1 The helicopter deck stiffening is to be designed for the load cases given in Table 5.6.2 with the helicopter being positioned so as to produce the most severe loading condition for each structural member under consideration.

6.4.2 The minimum requirements for section modulus, inertia and web area of secondary stiffeners are to be in accordance with Table 5.3.3.

6.4.3 For primary stiffening, and where a grillage arrangement is adopted, it is recommended that direct calculation procedures be used to determine the scantling requirements, in association with the limiting permissible stress criteria given in Chapter 7. A copy of the calculations is to be submitted for consideration.

■ *Section 7*
Strengthening requirements for navigation in ice conditions

7.1 General

7.1.1 The strengthening requirements detailed in this Section are applicable to craft, other than those assigned the notation **HSC** and/or **LDC** (*see* Pt 1, Ch 2), intended for operation in light first year ice conditions in areas other than the northern Baltic corresponding to unbroken level ice of thickness not greater than 0,4 m.

7.1.2 Craft complying with the requirements of this Section, in addition to the requirements for sea-going service where applicable, will be eligible for the special features notation **Ice Class 1D**. Alternatively, a Special Duties Notation may be assigned indicating that the craft has been additionally strengthened for duties in ice, *see* Pt 1, Ch 2,3.8.

7.1.3 Craft designed to operate in ice conditions other than those detailed in 7.1.1 are to comply with Part 8 of the Rules for Ships.

7.1.4 The requirements of this Section are applicable to both longitudinally and transversely framed craft and concern the shell plating and framing in the forward region, the stem, sternframe, rudder and the steering gear.

7.1.5 The vertical extent of the ice strengthening is related to the ice light and ice load waterlines, which are defined in 7.2. The maximum and minimum Ice Class draughts at both the fore and aft ends will be stated on the Class Certificate.

Table 5.6.2 Design load cases for deck stiffening and supporting structure

Loadcase	Loads (tonnes)			
	Landing area		Supporting structure, *see* Note 1	
	UDL	Helicopter, *see* Note 2	Self weight	Horizontal load, *see* Note 2
(1) Overall distributed loading	2	—	—	—
(2) Helicopter emergency landing	0,2	$2{,}5P_h f$	W_h	$0{,}5P_h$
(3) Normal Usage	0,5	$1{,}5P_h$	W_h	$0{,}5P_h + 0{,}5W_h$
Symbols				
P_h and f are as defined in 6.3.1 UDL = Uniformly distributed vertical load over entire landing area, kN/m^2 W_h = structural weight of helicopter platform, in tonnes				
NOTES 1. For the design of the supporting structure for helicopter platforms applicable self weight and horizontal loads are to be added to the landing area loads. 2. The helicopter is to be so positioned as to produce the most severe loading condition for each structural member under consideration.				

7.1.6 The requirements of this Section assume that when approaching ice infested waters the craft's speed will be reduced appropriately. The vertical extent of ice strengthening for craft intended to operate in ice conditions at speeds exceeding 15 knots will be specially considered.

7.1.7 The ballast capacity of propeller-driven craft is to be sufficient to give adequate propeller immersion in all ice navigating conditions without trimming the craft in such a manner that the actual waterline at the bow is below the ice light waterline. Ballast tanks situated above the ice light waterline and adjacent to the shell, which are intended to be used in ice navigating conditions, are to be provided with heating pipes.

7.2 Definitions

7.2.1 The Ice Load Waterline is that corresponding to the Fresh Water Summer Loadline.

7.2.2 The Ice Light Waterline is that corresponding to the lightest condition in which the craft is expected to navigate in ice.

7.2.3 The Ice Load Waterline and the Ice Light Waterline are to be indicated on the plans. For navigation in certain geographical areas, the relevant National Authority may require the maximum Ice Class draught to be marked on the craft in a specified manner.

7.2.4 The Main Ice Belt Zone extends vertically from 500 mm below the Ice Light Waterline to 400 mm above the Ice Load Waterline and horizontally from the stem to 0,02L m aft of the point at which the deepest load waterline reaches its greatest breadth.

7.3 Powering of ice strengthened craft

7.3.1 Ice strengthened craft are assumed to be capable of developing sufficient thrust to permit continuous mode icebreaking at a speed of at least five knots in ice having a thickness of 0,4 m and a snow cover of at least 0,3 m.

7.4 Shell plating

7.4.1 In way of the main ice belt zone, the thickness of the shell plating is to be determined by direct calculation. A copy of these direct calculations are to be submitted for consideration.

7.4.2 Changes in plating thicknesses in the longitudinal direction are to take place gradually.

7.4.3 Side scuttles are not to be situated in the ice belt.

7.4.4 If the weather deck in any part of the craft is situated below the upper limit of the ice belt, the bulwark is to be reinforced to the same degree as the shell plating in the main ice belt.

7.4.5 In general all welded seams and butts in way of the main ice belt are to be dressed smooth.

7.5 Shell framing requirements

7.5.1 Ice framing is to extend a minimum distance of 1000 mm above the Ice Load Waterline and 1600 mm below the Ice Light Waterline between the stem and 0,02L_R m aft of the point at which the deepest load waterline reaches its greatest breadth.

7.5.2 The web thickness of ice framing is not, in general, to be less than half that of the attached shell plating.

7.5.3 Ice frames are to be attached to the shell plating by double continuous welding and are not to be scalloped except at shell plating seams or butts. Air and drain holes are to be kept to a minimum.

7.5.4 Main and intermediate frames within the minimum extent of ice framing are to be efficiently supported to prevent tripping. The distance between anti-tripping supports is not to exceed 1000 mm.

7.5.5 The section modulus of an ice framing stiffening member is to be determined by direct calculation. A copy of these direct calculations is to be submitted for consideration.

7.5.6 Where transverse framing is adopted, ice stringers (primary longitudinal members supporting ice framing) are to be spaced not more than 1000 mm apart and are to have a section modulus not less than four times the section modulus of the transverse framing.

7.5.7 Where longitudinal framing is adopted, ice stringers need not be fitted.

7.6 Stem construction

7.6.1 Where a plate stem is fitted, the plate thickness is to be not less than 1,3 times that determined by Ch 3,3.3.

7.6.2 Where a bar stem is fitted, its cross-sectional area is to be not less than 1,25 times that determined by Ch 3,5.12.

7.7 Stern construction

7.7.1 A transom stern is not normally to extend below the ice load waterline. Where this cannot be avoided, the transom is to be kept as narrow as possible and the scantlings of plating and stiffeners are to be as required for the midcraft region.

7.8 Bossings and shaft struts

7.8.1 For craft with two or more propellers, shafting and sterntubes are generally to be enclosed within plated bossings. If detached supporting struts are necessary, their design, strengthening and attachment to the hull will be specially considered.

7.9 Rudder and steering arrangements

7.9.1 Rudder posts, rudder horns, solepieces, rudder stocks and pintles are to be dimensioned in accordance with Pt 3, Ch 3,2. The speed used in the calculations is to be the service speed or 14 knots, whichever is the greater.

7.9.2 The thickness of rudder plating and webs is to be increased by 10 per cent over the requirements of Pt 3, Ch 3,2.

7.9.3 Due regard is to be paid to the method of securing the rudder in the centreline position when backing into ice. Where possible, rudder stoppers working on the blade or rudder head are to be fitted.

7.9.4 Where steering nozzles are fitted, the thickness of the shroud plating is to include an abrasion allowance of 2 mm.

7.9.5 The scantlings of the stock, pintles, gudgeon and sole pieces associated with the nozzle are to be increased on the basis given in 7.9.1. However, the diameter of the nozzle stock is to be not less than that calculated in the astern condition taking the astern speed as seven knots or the actual astern speed, whichever is the greater.

7.9.6 Nozzles with articulated flaps will be subject to special consideration.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements for longitudinal and transverse global strength for mono-hull and multi-hull craft of aluminium construction, are contained within this Chapter. Due consideration is taken of the dynamic effects, where appropriate, in both the crest and trough wave loading conditions.

1.2 Symbols and definitions

1.2.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate sub-Section:

l = length of stiffening member, in metres

l_e = effective span length of stiffening member, in metres

p = design pressure as appropriately given in Part 3, in kN/m^2

s = spacing of stiffener, in mm

t_p = thickness of plating, in mm

B = moulded breadth of craft, in metres (to be taken as the breadth of a single hull for multi-hull craft)

L_R = Rule length of the craft, in metres

β = panel aspect ratio correction, *see* Ch 3,1.15

σ_a = 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2

$$\tau_a = \frac{\sigma_a}{\sqrt{3}}$$

1.2.2 The strength deck is to be taken as follows:

(a) Where there is a complete upper deck the strength deck is the upper deck.

(b) Where the upper deck is stepped, as in the case of raised quarterdeck craft, the strength deck is stepped as shown in Fig. 6.1.1.

1.3 General

1.3.1 The additional pressures arising from the influence of the global loading are considered in the determination of the longitudinal strength requirements for local and secondary stiffening and bottom shell plating.

1.3.2 In general, the effective sectional area of continuous longitudinal strength members, after deduction of openings, is to be used for the calculation of midship section modulus.

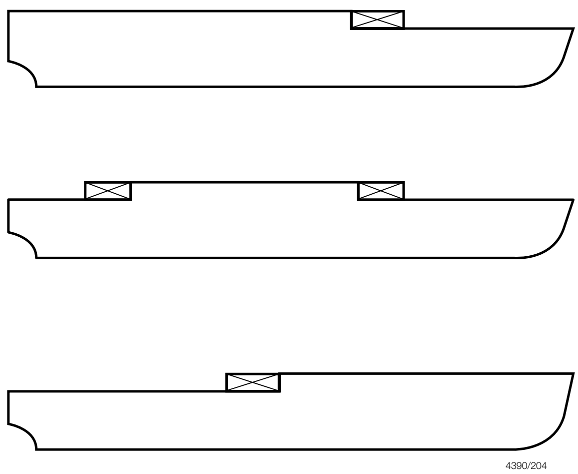


Fig. 6.1.1 Strength deck

1.3.3 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performances.

1.3.4 In general, superstructures or deckhouses will not be accepted as contributing to the global longitudinal or transverse strength of the craft. However, where it is proposed to include substantial, continuous stiffening members, special consideration will be given to their inclusion on submission of the designer's/Builder's calculations.

1.3.5 Where continuous deck longitudinals or deck girders are arranged above the strength deck, special consideration may be given to the inclusion of their sectional area in the calculation of the hull section modulus (Z). The lever is to be taken to a position corresponding to the depth of the longitudinal member above the moulded deckline at side amidships. Each such case will be individually considered.

1.3.6 Adequate transition brackets are to be fitted at the ends of effective continuous longitudinal strength members in the deck and bottom structures.

1.3.7 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section stiffness requirements determined from 2.2 are to be maintained within 0,4L_R amidships. However, in special cases, based on consideration of type of craft, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the 0,4L_R part, bearing in mind the desire not to inhibit the craft's loading and operational flexibility.

1.4 Openings

1.4.1 Deck openings having a length in the fore and aft directions exceeding 0,1*B* m or a breadth exceeding 0,05*B* m are in all cases to be deducted from the sectional areas used in the section modulus calculation.

1.4.2 Deck openings smaller than stated in 1.4.1, including manholes, need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths (*see* 1.4.3) in one transverse section does not exceed 0,06 ($B_o - \Sigma\, b_o$):

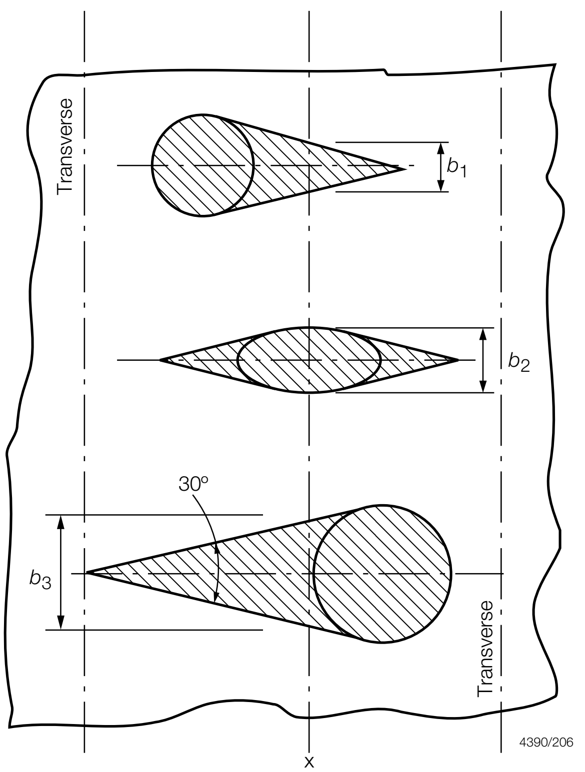
where

B_o = breadth of craft, in metres, at section considered

$\Sigma\, b_o$ = sum of breadths, in metres, of deductible openings

Where a large number of deck openings are proposed in any transverse space, special consideration will be required.

1.4.3 Where calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in Fig. 6.1.2. The shadow area is obtained by drawing two tangent lines to an opening angle of 30°. The section to be considered is to be perpendicular to the centreline of the ship and is to result in the maximum deduction in each transverse space.



Total equivalent breadth of small openings at xx = $b_1 + b_2 + b_3$

Fig. 6.1.2 Isolated openings

1.4.4 Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth or 75 mm, whichever is the lesser.

1.4.5 Openings are considered isolated if they are spaced not less than 1 m apart.

1.4.6 A reduction for drainage holes and scallops in beams and girders, etc., is not necessary so long as the original section stiffness at deck or keel is reduced by no more than three per cent.

1.5 Direct calculation procedure

1.5.1 In direct calculation procedures capable of deriving the wave induced loads on the craft, and hence the required modulus, account is to be taken of the craft's actual form and weight distribution.

1.5.2 Lloyd's Register's (hereinafter referred to as 'LR') direct calculation method involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval are normally to contain these three elements and produce similar and consistent results when compared with LR's methods.

1.6 Approved calculation systems

1.6.1 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from LR, calculations using the system for a particular craft may be submitted.

1.7 Information required

1.7.1 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR's standard format where appropriate:

(a) General arrangement and capacity plan or list, showing details of the volume and position of centre of gravity of all tanks and compartments.
(b) Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull. A lines plan and/or tables of offsets may also be required.
(c) Details of the calculated lightweight and its distribution.
(d) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions. It is recommended that this information be submitted in the form of a preliminary Loading Manual, to include the calculated still water and dynamic bending moments and shear forces.

1.8 Loading guidance information

1.8.1 Sufficient information is to be supplied to the Master of every craft to enable him to arrange loading in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

■ *Section 2*
Hull girder strength for mono-hull craft

2.1 General

2.1.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 45 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

2.1.2 For craft of ordinary hull form with a Rule length, L_R, less than 45 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the form, constructional arrangement and proposed loading.

2.1.3 Where the Rule length, L_R, of the craft exceeds 75 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

2.2 Bending strength

2.2.1 The effective geometric properties of the midship section are to be calculated directly from the dimensions of the section using only the effective material elements which contribute to the global longitudinal strength. For the purposes of this analysis an element may be of deck plating, longitudinal girder, inner bottom, etc., or other continuous member.

2.2.2 The longitudinal strength of craft with $\dfrac{V}{\sqrt{L_{WL}}} \geq 3{,}0$

is to satisfy both the following criteria:

$\sigma_k + \sigma_l + \sigma_t < 1{,}2\sigma_P$

$\sigma_d < \sigma_P$

where

σ_P = maximum permissible hull vertical bending stress, in N/mm^2
$= f_{\sigma gH}\,\sigma_a$

$f_{\sigma gH}$ = limiting hull bending stress coefficient taken from Table 7.3.2 in Chapter 7

L_{WL} is as defined in Pt 3, Ch 1,6.2.5

σ_k, σ_l, σ_t and σ_d are given in Table 6.2.1

σ_a is as defined in 1.2.1.

Table 6.2.1 Longitudinal component stresses

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships	$\sigma_d = \dfrac{M_R}{1000Z_d}$
Hull girder bending stress at keel amidships	$\sigma_k = \dfrac{M_R}{1000Z_k}$
Actual stress in bottom longitudinals amidships due to design pressure load	$\sigma_l = \dfrac{p_s\, s\, l_e^2}{12Z_l}$
Actual stress in bottom plating amidships due to design pressure load	$\sigma_t = 0{,}34p_t\left(\dfrac{\beta s}{t_p}\right)^2 \times 10^{-3}$
Symbols and definitions	
M_R = design longitudinal midship bending moment, in kNm given in Pt 5, Ch 5,5 p_s = additional effective pressure loading, in kN/m^2, on bottom longitudinals from global dynamic load model, given in Pt 5, Ch 5,2.6.3 p_t = additional effective pressure loading, in kN/m^2, on bottom plating from global dynamic load model, given in Pt 5, Ch 5,2.6.4 Z_d = actual section modulus at deck, in m^3 Z_k = actual section modulus at keel, in m^3 Z_l = maximum section modulus of bottom longitudinal stiffener, associated with plating, amidships, in cm^3 s, l_e, β and t_p are as defined in 1.2.	

2.2.3 The longitudinal strength of craft with $\dfrac{V}{\sqrt{L_{WL}}} < 3{,}0$

is to satisfy both the following criteria:

$\sigma_k < \sigma_P$

$\sigma_d < \sigma_P$

where

σ_P is as defined in 2.2.2

σ_k and σ_d, are given in Table 6.2.1

L_{WL} is as defined in Pt 3, Ch 1,6.2.5.

2.3 Shear strength

2.3.1 The shear strength of the craft at any position along its length is to satisfy the following criterion:

$$\frac{Q_R}{A_\tau}\,10^{-3} \leq \tau_p$$

where

Q_R = design hull shear force at any section along the hull length, L_R, in kN determined from Pt 5, Ch 5,5

A_τ = shear area of transverse section, in m^2, is to be taken as the effective net sectional area of the shell plating and longitudinal bulkheads after deductions for openings. For longitudinal strength members which are inclined to the vertical, the area of the member to be included in the calculation is to be based on the area projected onto the vertical plane, *see* Fig. 6.2.1

τ_p = maximum permissible mean shear stress, in N/mm^2
= $f_{\sigma g}\,\tau_a$

$f_{\sigma g}$ = limiting hull shear stress coefficient taken from Table 7.3.2 in Chapter 7

τ_a is as defined in 1.2.1.

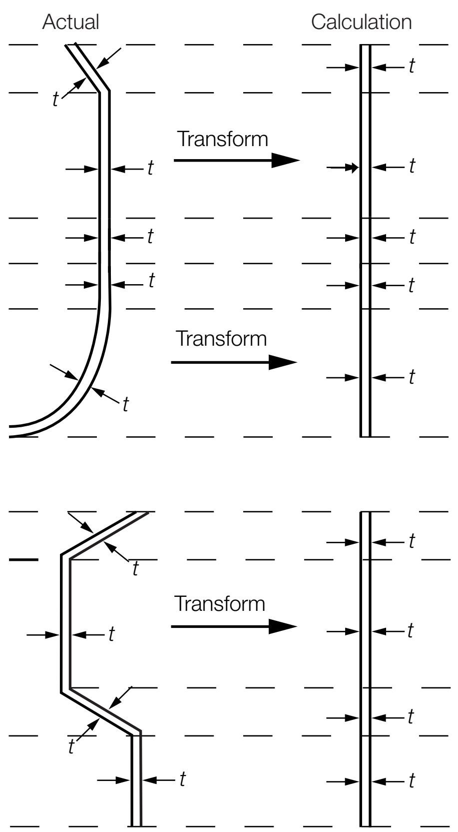


Fig. 6.2.1 Effective shear area

2.4 Torsional strength

2.4.1 Torsional stresses are typically small for mono-hulls of ordinary form of Rule length, L_R, less than 75 m and can generally be ignored.

2.4.2 The calculation of torsional stresses and/or deflections may be required when considering craft with large deck openings, unusual form or proportions. Calculations may in general be required to be carried out using a direct calculation procedure. Such calculations are to be submitted in accordance with 1.5.

2.5 Superstructures global strength

2.5.1 The effectiveness of the superstructure in absorbing hull girder bending loads is to be established where the first tier of the superstructure extends within 0,4*L* amidship and where:

$$l_d > b_d + 3h_d$$

where

l_d = length of first tier, in metres
b_d = breadth of first tier, in metres
h_d = 'tween deck height of first tier, in metres.

2.5.2 For superstructures with one or two tiers extending outboard to the craft's side shell, the effectiveness in absorbing hull girder bending loads in the uppermost effective tier may be assessed by the following factor:

$$\eta_s = 7\left[(\varepsilon - 5)\,\gamma^4 + 94\,(5 - \varepsilon)\,\gamma^3 + 2800\,(\varepsilon - 5{,}8)\,\gamma^2 + 27660\,(9 - \varepsilon)\,\gamma\right] f(\lambda, N) \times 10^{-7}$$

where

$f(\lambda, N = 1) = 1$

$f(\lambda, N = 2) = 0{,}90\lambda^3 - 2{,}17\lambda^2 + 1{,}73\lambda + 0{,}50$

and

N = 1 if $l_2 < 0{,}7l_1$
= 2 if $l_2 \geq 0{,}7l_1$

$\lambda = \dfrac{l_w}{L_R}$ or 1, whichever is less

$\varepsilon = \dfrac{b_1}{h_1}$ or 5, whichever is less

$\gamma = \dfrac{l_w}{h_1}$ or 25, whichever is less

$l_w = l_1$ for $N = 1$
$= \dfrac{(2l_1 + l_2)}{3}$ for $N = 2$

L_R = is as defined in 1.2.1, in metres
l_1, b_1, h_1 = is as defined in 2.5.1, in metres
l_2 = length of second tier, in metres.

2.5.3 The hull girder compressive bending stress σ_L, in the uppermost effective tier at side may be derived according to the following formula:

$$\sigma_L = \eta_s\,\frac{M_R}{1000Z_{100}}\ \text{N/mm}^2$$

where

M_R = hull girder bending moment at midships due to sagging as determined in Pt 5, Ch 5,5, in kNm
Z_{100} = section modulus at uppermost effective tier of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^3
η_s = as defined in 2.5.2.

2.5.4 The compressive stress, σ_L, in the uppermost effective tier at side is to be checked against buckling in accordance with Ch 7,4.

2.5.5 The uppermost effective tier may need to fulfil the requirements for strength deck when the following applies:

$$\eta_s = \left(1 + \frac{Z_0 h}{I_{100}}\right)^{-1}$$

where
η_s = as defined in 2.5.2
Z_0 = section modulus of hull only at hull upper deck, in m^3
I_{100} = moment of inertia of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^4
h = height from hull upper deck to uppermost effective tier, in metres.

■ *Section 3* Additional hull girder strength requirements for multi-hull craft

3.1 General

3.1.1 Except as otherwise specified within this Section, the global strength requirements for multi-hull craft are to comply with Section 2.

3.1.2 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 40 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

3.1.3 For craft of ordinary hull form length with a Rule length, L_R, less than 40 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the proposed loading.

3.1.4 Where the Rule length, L_R, of the craft exceeds 60 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

3.1.5 The strength deck plating in way of the cross-deck structure, the wet-deck plating, longitudinal bulkheads and girders, and other continuous members may be included in the determination of the midship section stiffness.

3.1.6 Special consideration will be given to the global strength requirements for craft with more than two hulls linked by cross-deck structure.

3.2 Hull longitudinal bending strength

3.2.1 The requirements of 2.2 are in general to be complied with, using the appropriate design bending moment and effective pressure loadings applicable to multi-hull craft, as determined from Pt 5, Ch 5,5.

3.3 Hull shear strength

3.3.1 The requirements of 2.3 are to be complied with so far as they are applicable.

3.4 Torsional strength

3.4.1 Where a craft is of unusual form or novel construction, or at the discretion of LR, the torsional stress is to be determined by direct calculation methods using the twin hull torsional connecting moment as defined in Pt 5, Ch 5,5. Such calculations are to be submitted in accordance with 1.5.

3.5 Strength of cross-deck structures

3.5.1 Design loads to be applied for scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 5.

3.5.2 The primary stiffening members of the cross-deck structure are to provide sufficient strength to satisfy the stress criteria given in Table 6.3.1.

Table 6.3.1 Primary member stress criteria

Stress type	Component stresses	Allowable stress level (N/mm^2)
Total direct stress, σ_P	$\sigma_P = \sigma_{MB} + \sigma_{MT} + \sigma_d$	$f_{\sigma gV}\,\sigma_a$
Total shear stress, τ_P	$\tau_P = \tau_T + \tau_{MBT} + \tau_{MT}$	$f_{\tau gV}\,\tau_a$
Equivalent stress, σ_{eq}	$\sigma_{eq} = \sqrt{\sigma^2 + 3\tau^2}$	1,2 $f_{\sigma eg}\,\sigma_a$
Symbols and definitions		
σ_{MB}, σ_{MT}, τ_T, τ_{MBT} and τ_{MT} are component stresses, in N/mm^2, to be taken from Table 6.3.2. $f_{\sigma gV}$, $f_{\tau gV}$ and $f_{\sigma eg}$ are limiting stress coefficients for cross-deck structures to be taken from Table 7.3.2 in Chapter 7. σ_a and τ_a are defined in 1.2.		

3.5.3 The component nominal stresses may be determined in accordance with Table 6.3.2 in the case where the cross-deck is formed by transverse primary stiffeners or bulkheads and the following assumptions are taken:

(a) The cross-deck is symmetrical forward and aft of a transverse axis at its half length.

(b) Primary stiffeners having the same scantlings and spacing.

3.5.4 Other cross-deck designs subjected to global transverse loads will require a two-dimensional grillage analysis to be performed to demonstrate compliance with 3.5.2.

3.5.5 Section properties are to be calculated using an effective breadth of plating to be determined in accordance with Ch 3,1.11.

3.5.6 Where primary stiffening members support areas of plating of the extruded plank type, or the floating frame system is used, the effect of the plating attached to the secondary stiffening members is to be ignored when determining the global section modulus requirements.

3.6 Grillage structures

3.6.1 For complex girder systems, a complete structural analysis using numerical methods may be required to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

3.6.2 In general, the transverse and vertical girders, bottom and side structures, bridge structure, deck structures and any other parts of the craft which LR considers critical to the craft's structural integrity are to be included in the numerical modelling of the craft.

3.7 Analysis techniques

3.7.1 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

3.7.2 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

3.7.3 Analysis of the cross deck structures with regard to impact loads due to slamming may have to be carried out using advanced structural analysis techniques.

Table 6.3.2 Cross-deck component stresses for designs complying with 3.5.3

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships, *see* Table 6.2.1	$\sigma_d = f_{MR} \dfrac{M_R}{1000 Z_d}$
Stress induced by the transverse bending moment M_B, as defined in Pt 5, Ch 5,5	$\sigma_{MB} = f_{MB} \dfrac{M_B}{nZ} 10^3$
Stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\sigma_{MT} = f_{MT} \dfrac{3 x_H M_T}{n (n + 1) s_p Z} 10^3$
Shear stress induced by the vertical shear force Q_T, as defined in Pt 5, Ch 5,5	$\tau_T = f_{MB} \dfrac{5 Q_T}{n A_w}$
Bending shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\tau_{MBT} = f_{MT} \dfrac{60 M_T}{n (n + 1) s_p A_w}$
Shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\tau_{MT} = f_{MT} \dfrac{46 \kappa x_H^2 M_T}{n (n^2 + 1) s_p^2 I_y} 10^3$
Symbols and definitions	
Q_T = vertical shear force, in kN, as determined from, Pt 5, Ch 5,5 M_B = transverse bending moment in kNm, as determined from Pt 5, Ch 5,5 M_T = torsional moment in kNm, as determined from Pt 5, Ch 5,5 n = total number of transverse primary stiffeners or bulkheads A_w = stiffener web area, cm^2 Z = primary stiffeners section modulus, in cm^3 s_p = stiffener spacing, in metres I_y = moment of inertia of stiffener, cm^4 x_H = transverse distance between the centre of the two hulls, in metres κ = t_f, for symmetrical I-section, in mm = $b_b h/(b_b + h)$, for constant thickness box sections, in mm σ_{MB} = stress induced by the transverse bending moment M_B, as defined in Pt 5, Ch 5,5, in N/mm^2 σ_{MT} = stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2 τ_T = shear stress induced by the vertical shear force Q_T, as defined in Pt 5, Ch 5,5, in N/mm^2 τ_{MBT} = bending shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2 τ_{MT} = shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2 t_f = face plate thickness, in mm b_b = breadth of box section, in mm h_b = height of box section, in mm f_{MR}, f_{MB} and f_{MT} are load combination factors reflecting the portions of each component global design load, M_R, Q_T, M_B and M_T, corresponding to the most severe load combinations, The most severe load combinations are the combinations of loads resulting in the maximum bending, shear and effective stress, respectively. The assessment of these load combinations need to take due consideration for the component load magnitude variation with wave heading and also the phasing in time between them. Generally, f_{MR}, f_{MB}, and f_{MT} are to be taken as indicated in Table 6.3.3.	

Table 6.3.3 Load combination factors

Heading	Factors		
	f_{MB}	f_{MR}	f_{MT}
Head sea	0,1	1,0	0,1
Beam sea	1,0	0,1	0,2
Quartering sea	0,1	0,4	1,0

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of aluminium construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 The failure modes criteria contained within this Chapter are to be used in the formulae from the preceding Chapters to determine the scantling requirements. In addition, they are to be used when direct calculation methods are proposed as an alternative.

1.3 Symbols and definitions

1.3.1 The symbols and definitions applicable to this Chapter are defined in the appropriate Sections.

1.4 Direct calculations

1.4.1 Where direct calculations are proposed, the requirements of Pt 3, Ch 1,2 are to be complied with.

1.4.2 In addition, with the agreement of Lloyd's Register (hereinafter referred to as 'LR'), tests may be conducted to demonstrate the actual response of the structure and the results verified against the failure mode criteria in this Chapter.

■ *Section 2* Deflection control

2.1 General

2.1.1 The limiting deflection requirements for plate panels and stiffening members are given in terms of limiting deflection coefficient, f_δ, *see* Table 7.2.1. The coefficient equates to a span/deflection ratio in consistent units.

Table 7.2.1 Limiting deflection ratio

Item		Deflection ratio, f_δ
Bottom structure:		
	• secondary stiffening	475
	• primary girders and web frames	625
Side structure:		
	• secondary stiffening	475
	• primary girders and web frames	625
Main/strength deck structures:		
	• secondary stiffening	625
	• primary girders and web frames	775
	• hatch covers	775
Superstructures/deckhouses stiffeners:		
(a) Generally:	• secondary	400
	• primary	475
(b) Coachroof:	• secondary	475
	• primary	625
(c) House top:	• secondary	400
	• primary	400
Lower/inner decks and house top, subject to personnel loading:		
	• secondary members	475
	• primary members	625
Deep tank stiffeners:		
	• secondary members	625
	• primary members	775
Watertight bulkhead stiffeners:		
	• secondary members	400
	• primary members	475
Multi-hull cross-deck stiffeners:		
	• secondary members	475
	• primary members	625
Vehicle deck stiffeners:		
	• secondary members	625
	• primary members	775
Helicopter/flight deck stiffeners:		
	• secondary members	625
	• primary members	775
NOTE Where significant curvature exists over the span of the stiffener or breadth of the panel, the allowable deflections will be specially considered.		

■ *Section 3*
Stress control

3.1 General

3.1.1 The nominal limiting stress requirements for plating and primary and secondary stiffening members subject to local loading conditions are given in terms of limiting stress coefficients, *see* Table 7.3.1. The coefficients are expressed as a proportion of the 0,2 per cent proof stress of the material.

3.1.2 The limiting stress coefficients for structural elements subject to global loading conditions are given in Table 7.3.2.

3.1.3 In the determination of the magnitude of the equivalent stress, σ_{eq}, it is assumed that the stresses are combined using the following formula:

$$\sigma_{eq} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau^2}$$

where

σ_x = direct stress in the x direction

σ_y = direct stress in the y direction

τ = shear stress in the xy plane.

Table 7.3.1 Limiting stress coefficients for local loading (*see continuation*)

Item		Limiting stress coefficient		
		Bending f_σ	Shear f_τ	Equivalent f_e
Shell envelope:				
(a) Bottom shell plating:	• slamming zone	0,85	—	—
	• elsewhere	0,75	—	—
(b) Side shell plating:	• slamming zone	0,85	—	—
	• elsewhere	0,75	—	—
(c) Keel		0,75	—	—
Bottom structure:				
(a) Secondary stiffening:	• slamming zone	0,75	0,75	—
	• elsewhere	0,65	0,65	—
(b) Primary girders and web frames		0,65	0,65	0,75
(c) Engine girders		0,55	0,55	0,75
Side structure:				
(a) Secondary stiffening:	• slamming zone	0,75	0,75	—
	• elsewhere	0,65	0,65	—
(b) Primary girders and web frames		0,65	0,65	0,75
Bow doors:				
(a) Plating		0,65	—	—
(b) Secondary stiffening		0,51	0,433	—
(c) Primary stiffening		0,51	0,34	0,64
Main/strength deck plating and stiffeners:				
(a) Plating		0,75	—	—
(b) Secondary stiffening		0,65	0,65	—
(c) Primary girders and web frame		0,65	0,65	0,75
(d) Hatch covers		0,55	0,55	0,64

Table 7.3.1 Limiting stress coefficients for local loading (*conclusion*)

Item		Limiting stress coefficient		
		Bending f_σ	Shear f_τ	Equivalent f_e
Superstructures/deckhouses:				
(a) Deckhouse front, 1st tier:	• plating	0,65	—	—
	• stiffening	0,60	0,60	—
(b) Deckhouse front, upper tiers:	• plating	0,75	—	—
	• stiffening	0,65	0,65	—
(c) Deckhouse aft and sides:	• plating	0,75	—	—
	• stiffening	0,75	0,75	—
(d) Coachroof:	• plating	0,65	—	—
	• stiffening	0,65	0,65	—
(e) House top:	• plating	0,75	—	—
	• stiffening	0,75	0,75	—
(f) Lower/inner decks and house top, subject to personnel loading:				
	• plating	0,75	—	—
	• stiffening	0,60	0,60	—
Bulkheads:				
(a) Watertight bulkhead:	• plating	1,0	—	—
	• secondary stiffening	0,95	0,95	—
	• primary stiffening	0,90	0,90	1,0
(b) Watertight bulkhead doors		0,825	0,825	0,825
(c) Structure supporting watertight doors		0,80	0,80	—
(d) Minor bulkheads:	• plating	0,65	—	—
	• secondary stiffening	0,65	0,65	—
	• primary stiffening	0,65	0,65	0,75
(e) Deep tank bulkheads:	• plating	0,65	—	—
	• secondary stiffening	0,65	0,65	—
	• primary stiffening	0,75	0,75	—
Multi-hull cross-deck structure:				
(a) Plating:	• slamming zone	0,85	—	—
	• elsewhere	0,75	—	—
(b) Secondary stiffening:	• slamming zone	0,75	0,75	—
	• elsewhere	0,65	0,65	—
(c) Primary stiffening		0,65	0,65	0,75
Vehicle deck:				
(a) Plating		0,60	—	—
(b) Secondary stiffening		0,425	0,425	—
(c) Primary stiffening		0,525	0,525	0,75
Helicopter/flight decks:				
(a) Normal usage:	• plating	0,65	—	—
	• secondary stiffening	0,75	0,75	—
	• primary stiffening	0,625	0,625	0,60
(b) Emergency landing:	• plating	0,75	—	—
	• secondary stiffening	1,0	1,0	—
	• primary stiffening	0,825	0,825	0,9
(c) Crane pedestal/foundation structural elements		0,7	0,7	0,75

Table 7.3.2 Limiting stress coefficients for global loading

Operational mode of craft	Limiting stress coefficient					
	Hull girder			Cross-deck		
	Bending $f_{\sigma gH}$	Shear $f_{\tau gH}$	Equivalent $f_{\sigma eg}$	Bending $f_{\sigma gV}$	Shear $f_{\tau gV}$	Equivalent $f_{\sigma eg}$
$\Gamma \geq 3{,}0$ $\Delta \leq 0{,}04\ (L_R\, B)^{1,5}$	0,80	0,80	0,825	0,80	0,80	0,825
$\Gamma < 3{,}0$ and $\Delta > 0{,}4\ (L_R\, B)^{1,5}$	0,72	0,72	0,75	0,72	0,72	0,75

Symbols

$f_{\sigma gH}$ = limiting hull bending stress coefficient
$f_{\tau gH}$ = limiting hull shear stress coefficient
$f_{\sigma gV}$ = limiting cross-deck bending stress coefficient
$f_{\tau gV}$ = limiting cross-deck shear stress coefficient
$f_{\sigma eg}$ = limiting equivalent stress coefficient
Γ is the Taylor Quotient as defined in Pt 5, Ch 2,2.1.16
Δ is the displacement as defined in Pt 5, Ch 2,2
L_R and B are as defined in Pt 3, Ch 1,6.2

■ *Section 4* Buckling control

4.1 General

4.1.1 This Section contains the requirements for buckling control of plate panels subject to in-plane compressive and/or shear stresses and buckling control of primary and secondary stiffening members subject to axial compressive and shear stresses.

4.1.2 The requirements for buckling control of plate panels are contained in 4.3 to 4.6. The requirements for secondary stiffening members are contained in 4.7 to 4.8. The requirements for primary members are contained in 4.9 and 4.10.

4.1.3 In general all areas of the structure are to meet the buckling strength requirements for the design stresses. The design stresses are to be taken as follows:

(a) Global hull girder bending and shear stresses given in Chapter 6, but not including stresses σ_l and σ_t as defined in Table 6.2.1 in Chapter 6.
(b) Stresses from local compressive loads.

4.1.4 The buckling requirements are to be met using the net scantlings, hence any additional thickness for corrosion margin or Owner's extra is not included in scantlings used to assess the buckling performance.

4.2 Symbols

4.2.1 The symbols used in this Section are defined below and in the appropriate sub-Section:

a = panel length, i.e. parallel to direction of com-pressive stress being considered, in mm
b = panel breadth, i.e. perpendicular to direction of compressive stress being considered, in mm
b_{eb} = lesser of $1{,}9 t_p \sqrt{\dfrac{E}{\sigma_a}}$ or $0{,}8b$ mm
l = length of longer edge of plate panel, in metres
s = length of shorter edge of plate panel, in mm (typically the spacing of secondary stiffeners)
t_p = thickness of plating, in mm
A_R = panel aspect ratio
$= \dfrac{a}{b}$
A_{te} = cross-sectional area of secondary stiffener, in cm^2, including an effective breadth of attached plating, b_{eb}
E = modulus of elasticity of material in N/mm^2
S = spacing of primary member, in metres (measured in direction of compression)
S_p = span of primary members, in metres
σ_a = 0,2 per cent proof stress of the material, in N/mm^2
σ_e = elastic compressive buckling stress, in N/mm^2
σ_c = critical compressive buckling stress, including the effects of plasticity where appropriate, in N/mm^2
τ_a = specified minimum yield shear stress of the material, in N/mm^2
$= \dfrac{\sigma_a}{\sqrt{3}}$ N/mm^2
τ_e = elastic shear buckling stress, in N/mm^2
τ_c = critical shear buckling stress, in N/mm^2.

4.3 Plate panel buckling requirements

4.3.1 This Section gives methods for evaluating the buckling strength of plate panels subjected to the following load fields:
(a) uni-axial compressive loads;
(b) shear loads;
(c) bi-axial compressive loads;
(d) uni-axial compressive loads and shear loads;
(e) bi-axial compressive loads and shear loads.

4.3.2 The plate panel buckling requirements will be satisfied if the buckling interaction equations given in Table 7.4.2 for the above load fields are complied with.

4.3.3 The critical compressive buckling stresses and critical shear buckling stresses required for Table 7.4.2 are to be derived in accordance with 4.4.

4.3.4 The buckling factors of safety λ_σ and λ_τ required by Table 7.4.2 are given in Table 7.4.4 for the structural member concerned.

4.3.5 For all structural members which contribute to the hull girder strength, the plate panel buckling requirements for uni-axial compressive loads, Table 7.4.2(a), and shear loads, Table 7.4.2(b) are to be complied with.

4.3.6 In addition to 4.3.5, structural members which are subjected to local compressive loads and/or shear loads are to be verified using the plate panel buckling requirements in Table 7.4.2(c) to (e).

4.3.7 However, where some members of the structure have been designed such that elastic buckling of the plate panel between the stiffeners is allowable, then the requirements of 4.5 must be applied to the buckling analysis of the stiffeners supporting the plating. In addition, panels which do not satisfy the panel buckling requirements must be indicated on the appropriate drawing and the effect of these panels not being effective in transmitting compressive loads taken into account for the hull girder strength calculation.

4.3.8 In general the plate panel buckling requirements for more complex load fields, *see* 4.3.1(c), (d), (e), are to be complied with. Where this is not possible, due to elastic buckling of the panel, then the critical buckling stress, σ_c, may be based on the ultimate collapse strength of the plating, σ_u from 4.5.4, instead of the elastic buckling stress, σ_e, derived in 4.3.5. In addition, the requirements of 4.5 are to be met for the supporting secondary stiffeners and primary members.

4.4 Derivation of the buckling stress for plate panels

4.4.1 The critical compressive buckling stress, σ_c, for a plate panel subjected to uni-axial in-plane compressive loads is to be derived in accordance with Table 7.4.1(a).

4.4.2 The critical shear buckling stress, τ_c, for a plate panel subjected to pure in-plane shear load is to be derived in accordance with Table 7.4.1(b).

4.4.3 For welded plate panels the critical compressive buckling stress is to be reduced to account for the presence of residual welding stresses. The critical buckling stress is to be taken as the minimum of:

$\sigma_{cr} = \sigma_e - \sigma_r$

σ_c derived using 4.4.1

where

σ_r = reduction in compressive buckling stress due to residual welding stresses

$$= \frac{2\beta_{RS}\,\sigma_a}{b/t_p}$$

β_{RS} = residual stress coefficient dependent on type of weld (average value of β_{RS} to be taken as 3)

b, t_p and σ_a are defined in 4.2.1.

4.4.4 In general the effect of lateral loading on plate panels (for example hydrostatic pressure on bottom shell plating) may be neglected and the critical buckling stresses calculated considering the in-plane stresses only.

4.4.5 Unless indicated otherwise, the effect of initial deflection on the buckling strength of plate panels may be ignored.

4.5 Additional requirements for plate panels which buckle elastically

4.5.1 Elastic buckling of plate panels between stiffeners occurs when both the following conditions are satisfied:
(a) The design compressive stress, σ_d, is greater than the elastic buckling stress of the plating, σ_e,
$\sigma_d > \sigma_e$
(b) The elastic buckling stress is less than half the yield stress
$$\sigma_e \leq \frac{\sigma_a}{2}$$

4.5.2 Elastic buckling of local plating between stiffeners, including girders or floors, etc., may be allowed if all of the following conditions are satisfied:
(a) The critical buckling stress of the stiffeners in all buckling modes is greater than the axial stress in the stiffeners after redistribution of the load from the elastically buckled plating into the stiffeners, hence
$$\frac{\sigma_{de}}{\sigma_{c\,(i)}} \leq \frac{1}{\lambda_\sigma}$$
(b) Maximum predicted loadings are used in the calculations.
(c) Functional requirements will allow a degree of plating deformation.

where

σ_{de} is the stiffener axial stress given in 4.5.5

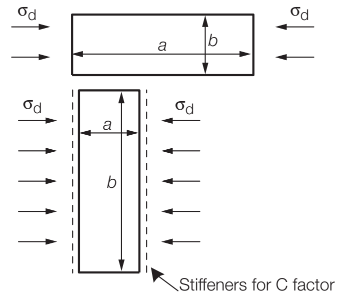
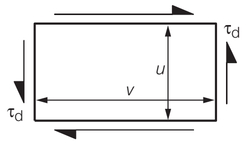
$\sigma_{c\,(i)}$ is given by Table 7.4.3

where

i = a, t, w or f depending on the mode of buckling

λ_σ is the buckling factor of safety
= 1,25.

Table 7.4.1 Buckling stress of plate panels

Mode	Elastic buckling stress, N/mm^2 *see* Note 1	
(a) Uni-axial compression: (i) Long narrow panels, loaded on the narrow edge (ii) Short broad panels, loaded on the broad edge	$A_R \geq 1$ $\sigma_e = 3{,}62\varphi E \left(\dfrac{t_p}{b}\right)^2$ $A_R < 1$ $\sigma_e = 0{,}9C\,\varphi \left(\dfrac{b}{a} + \dfrac{a}{b}\right)^2 E \left(\dfrac{t_p}{b}\right)^2$	
(b) Pure shear:	$\tau_e = 3{,}62\left(1{,}335 + \left(\dfrac{u}{v}\right)^2\right) E \left(\dfrac{t_p}{u}\right)^2$ NOTE u is to be the minimum dimension	

NOTE
The critical buckling stresses, in N/mm^2, are to be derived from the elastic buckling stresses as follows:

$$\sigma_c = \sigma_e \text{ when } \sigma_e < \frac{\sigma_a}{2}$$

$$= \sigma_a\left(1 - \frac{\sigma_a}{4\sigma_e}\right) \text{ when } \sigma_e \geq \frac{\sigma_a}{2}$$

σ_c is defined in 4.2.1
σ_a is defined in 4.2.1

$$\tau_c = \tau_e \text{ when } \tau_e < \frac{\tau_a}{2}$$

$$= \tau_a\left(1 - \frac{\tau_a}{4\tau_e}\right) \text{ when } \tau_e \geq \frac{\tau_a}{2}$$

τ_c is defined in 4.2.1
τ_a is defined in 4.2.1

Symbols

A_R = panel aspect ratio, *see* 4.2.1
σ_e = elastic compressive buckling stress, in N/mm^2
τ_e = elastic shear buckling stress, in N/mm^2
a and b are the panel dimensions in mm, *see* figures above
t_p = thickness of plating, in mm
φ = stress distribution factor for linearly varying compressive stress across plate width
= $0{,}47\mu^2 - 1{,}4\mu + 1{,}93$ for $\mu \geq 0$
= 1 for constant stress
$\mu = \dfrac{\sigma_{d1}}{\sigma_{d2}}$ where σ_{d1} and σ_{d2} are the smaller and larger average compressive stresses respectively

E = Young's Modulus of elasticity of material, in N/mm^2
C = stiffener influence factor for panels with stiffeners perpendicular to compressive stress
= 1,3 when plating stiffened by floors or deep girders
= 1,21 when stiffeners are built up profiles or rolled angles
= 1,10 when stiffeners are bulb flats
= 1,05 when stiffeners are flat bars
σ_d and τ_d are the design compressive and design shear stresses in the direction illustrated in the figures. With linearly varying stress across the plate panel, σ_d is to be taken as σ_{d2}

4.5.3 The effective breadth of attached plating for stiffeners, girder or beams that is to be used for the determination of the critical buckling stress of the stiffeners attached to plating which buckles elastically is to be taken as follows:

$$b_{eu} = \frac{b\sigma_u}{\sigma_a} \text{ mm}$$

where
σ_u = ultimate buckling strength of plating as given in 4.5.4
b_{eu} = effective panel breadth perpendicular to direction of compressive stress being considered
b is given in 4.2.1.

4.5.4 The ultimate buckling strength of plating, σ_u, which buckles elastically, may be determined as follows:
(a) shortest edge loaded, i.e. $A_R \geq 1$:

$$\sigma_u = \sigma_a\left(\frac{1{,}9}{\Omega} - \frac{0{,}8}{\Omega^2}\right) \text{ N/mm}^2$$

(b) longest edge loaded, i.e. $A_R < 1$:

$$\sigma_u = \frac{1{,}77\sigma_a A_R^{0{,}78}}{\Omega} \text{ N/mm}^2$$

where

$$\Omega = \frac{s}{t_p}\sqrt{\frac{\sigma_a}{E}}$$

A_R and s are defined in 4.2.1.
t_p, E and σ_a are defined in 4.2.1.

4.5.5 The axial stress in stiffeners attached to plating which is likely to buckle elastically is to be derived as follows:

$$\sigma_{de} = \sigma_d \frac{A_t}{A_{tb}}$$

where

σ_d is the axial stress in the stiffener when the plating can be considered fully effective

$$A_t = A_s + \frac{bt}{100} \text{ cm}^2$$

$$A_{tb} = A_s + \frac{b_{eu}\,t}{100} \text{ cm}^2$$

where

b and b_{eu} are given in 4.5.3

t is the plating thickness, in mm

A_s is the stiffener area in cm^2.

4.6 Shear buckling of stiffened panels

4.6.1 The shear buckling capability of longitudinally stiffened panels between primary members is to satisfy the following condition:

$$\frac{\tau_d}{\tau_c} \leq \frac{1}{\lambda_\tau}$$

where

τ_c is derived from 4.6.3

τ_d is the design shear stress

λ_τ is given in Table 7.4.4.

4.6.2 The elastic shear buckling stress of longitudinally stiffened panels between primary members may be taken as:

$$\tau_e = K_s E \left(\frac{t}{s}\right)^2 \quad \text{for } A_R \geq 1$$

where

$$K_s = 4{,}5\left(\left(\frac{s}{1000l}\right)^2 + \frac{1}{N^2} + \left(\frac{N^2 - 1}{N^2}\right)\left(\frac{\omega}{1 + \omega}\right)^r\right)$$

N = number of subpanels

$$= \frac{1000S_p}{s}$$

$$\omega = \frac{10I_{se}}{l\,t^3}$$

I_{se} = moment of inertia of a section, in cm^4, consisting of the longitudinal stiffener and a plate flange of effective width $s/2$

$$r = 1 - 0{,}75\left(\frac{s}{1000l}\right)$$

s, l, E and S_p are as defined in 4.2.1, *see also* Fig. 7.4.1.

4.6.3 The critical shear buckling stress, τ_c, may be determined from τ_e, *see* Note in Table 7.4.1.

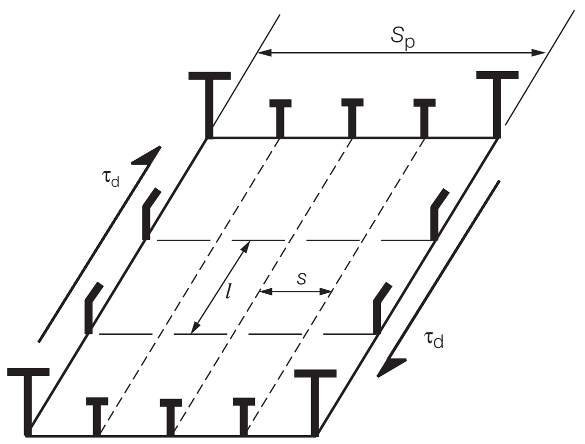


Fig. 7.4.1 Shear buckling of stiffened panels

4.7 Secondary stiffening in direction of compression

4.7.1 The buckling performance of stiffeners will be considered satisfactory if the following conditions are satisfied:

$$\frac{\sigma_d}{\sigma_{c(a)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(t)}} \leq \frac{1}{\lambda_\sigma}$$

$$\frac{\sigma_d}{\sigma_{c(w)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(f)}} \leq \frac{1}{\lambda_\sigma}$$

where

$\sigma_{c(a)}$, $\sigma_{c(t)}$, $\sigma_{c(w)}$ and $\sigma_{c(f)}$ are the critical buckling stresses of the stiffener for each mode of failure, *see* 4.7.2

σ_d is the design compressive stress, *see also* 4.5 and 4.1.3

λ_σ is the buckling factor of safety given in Table 7.4.4. The value of λ_σ to be chosen depends on the buckling assessment of the attached plating, *see* Note 1, Table 7.4.4.

4.7.2 The critical buckling stresses for the overall, torsional, web and flange buckling modes of longitudinals and secondary stiffening members under axial compressive loads are to be determined in accordance with Table 7.4.3.

4.7.3 To prevent torsional buckling of secondary stiffeners from occurring before buckling of the plating, the critical torsional buckling stress, $\sigma_{c(t)}$, is to be greater than the critical buckling stress of the attached plating as detailed in 4.4.1.

4.7.4 The critical buckling stresses of the stiffener web, $\sigma_{c(w)}$, and flange, $\sigma_{c(f)}$, are to be greater than the critical torsional buckling stress, hence:

$$\sigma_{c(w)} > \sigma_{c(t)}$$

$$\sigma_{c(f)} > \sigma_{c(t)}$$

4.7.5 To ensure that overall buckling of the stiffened panel cannot occur before local buckling of the secondary stiffener, the critical overall buckling stress $\sigma_{c(a)}$, is to be greater than the critical torsional buckling stress, hence

$$\sigma_{c(a)} > \sigma_{c(t)}$$

4.8 Secondary stiffening perpendicular to direction of compression

4.8.1 Where a stiffened panel of plating is subjected to a compressive load perpendicular to the direction of the stiffeners, *see* Fig. 7.4.2, e.g. a transversely stiffened panel subject to longitudinal compressive load, the requirements of this Section are to be applied.

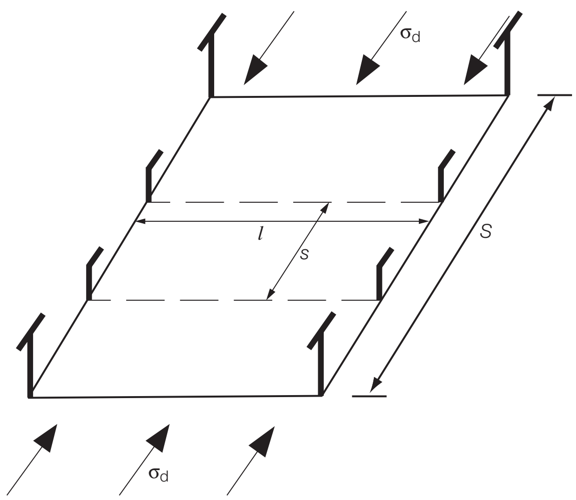


Fig. 7.4.2
Secondary stiffening perpendicular to direction of compression

4.8.2 The minimum area moment of inertia of each stiffener including attached plating of width, *s*, to ensure that overall panel buckling does not precede plate buckling is to be taken as:

$$I_s = \frac{D\, s\, (4N_L^2 - 1)((N_L^2 - 1)^2 - 2(N_L^2 + 1)\,\kappa + \kappa^2)}{2\,(5N_L^2 + 1 - \kappa)\,\Pi^4\, E} \text{ mm}^4$$

where

$D = \frac{E\, t_p^3}{12\,(1 - \upsilon^2)}$

$\kappa = A_R^2\, \Pi^2$

A_R = plate panel aspect ratio

$= \frac{s}{1000 l}$

$\Pi = \frac{S}{l}$

N_L = number of plate panels

$N_L - 1$ = number of stiffeners

υ = 0,3

s, *l* and *S* are defined in 4.2.1 and shown in Fig.7.4.2

t_p, *E* are defined in 4.2.1.

4.9 Buckling of primary members

4.9.1 Where primary girders are subject to axial compressive loading, the buckling requirements for lateral, torsional, web and flange buckling modes detailed in 4.7 are to be satisfied.

4.9.2 To prevent global buckling from occurring before local panel buckling, transverse primary girders supporting axially loaded longitudinal stiffeners are to have a sectional moment of inertia, including attached plating, of not less than the following:

$$I_g = \frac{0{,}35 S_p^4\, I_s}{l^3\, s} \times 10^3 \text{ cm}^4$$

S_p and *s* are as defined in 4.2.1, see also Fig.7.4.1

I_g = sectional moment of inertia including attached plating

I_s = moment of inertia of secondary stiffeners, in cm^4, required to satisfy the overall elastic column buckling mode requirement specified in Table 7.4.3

$= \frac{\sigma_{ep}\, A_{te}\, l_e^2}{0{,}001 E}$

where

$\sigma_{ep} = 1{,}2\sigma_d$ N/mm^2 for $\sigma_{e(a)} < \frac{\sigma_a}{2}$

$= \frac{\sigma_a^2}{4\,(\sigma_a - 1{,}2\sigma_d)}$ for $\sigma_{e(a)} \geq \frac{\sigma_a}{2}$

σ_d is design stress, in N/mm^2

σ_a and A_{te} are as defined in 4.2.1.

$\sigma_{e(a)}$ is the elastic column buckling stress, *see* 4.7.2

E is defined in 4.2.1

l_e is defined in Table 7.4.3.

4.10 Shear buckling of girder webs

4.10.1 Local panels in girder webs subject to in-plane shear loads are to satisfy the shear buckling requirements in Table 7.4.2, item (b).

4.10.2 The critical shear buckling stress, τ_c, is to be determined using the following formula for τ_e and the Note in Table 7.4.1.

$$\tau_e = 3{,}62\left(1{,}335 + \left(\frac{d_w}{1000 l_p}\right)^2\right) E \left(\frac{t_p}{d_w}\right)^2 \text{ N/mm}^2$$

where

d_w = web height, in mm

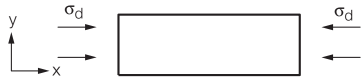
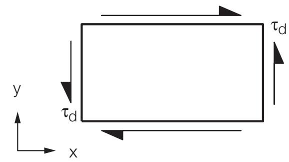
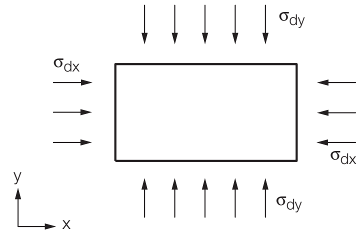
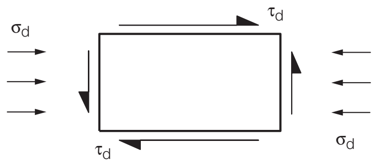
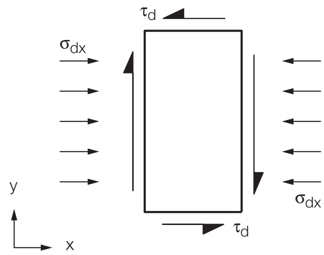
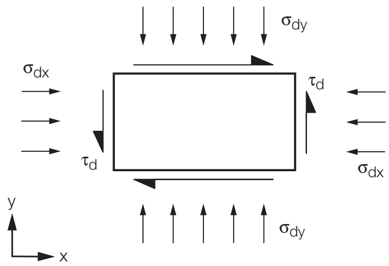
l_p = unsupported length of web, in metres

t_p and *E* are defined in 4.2.1.

4.11 Pillars and pillar bulkheads

4.11.1 Pillars and pillar bulkheads are to comply with the requirements of Ch 3,10.

Table 7.4.2 Plate panel buckling requirements

	Stress field	Buckling Interaction formula	
(a)	uni-axial compressive loads	$\dfrac{\sigma_d}{\sigma_c} \leq \dfrac{1}{\lambda_\sigma}$	
(b)	shear loads	$\dfrac{\tau_d}{\tau_c} \leq \dfrac{1}{\lambda_\tau}$	
(c)	bi-axial compressive loads	for A_R = 1,0 $\dfrac{\sigma_{dx}}{\sigma_{cx}} + \dfrac{\sigma_{dy}}{\sigma_{cy}} \leq 1{,}0$ for other aspect ratios, i.e. $A_R \neq 1{,}0$ $\dfrac{\sigma_{dx}}{\sigma_{cx}} + \dfrac{\sigma_{dy}}{\sigma_{cy}} \leq G$ when G is taken from Fig. 7.4.3	
(d)	uni-axial compressive loads plus shear load	for A_R > 1 $\left(\dfrac{\sigma_d}{\sigma_c}\right) + \left(\dfrac{\tau_d}{\tau_c}\right)^2 \leq 1$ for $A_R \leq 1$ $\left(\dfrac{1 + 0{,}6A_R}{1{,}6}\right)\left(\dfrac{\sigma_d}{\sigma_c}\right) + \left(\dfrac{\tau_d}{\tau_c}\right)^2 \leq 1$	 
(e)	bi-axial compressive loads plus shear loads	$\dfrac{0{,}625\left(1 + \dfrac{0{,}6}{A_R}\right)\left(\dfrac{\sigma_{dy}}{\sigma_{cy}}\right)}{1 - 0{,}625\left(\dfrac{\sigma_{dx}}{\sigma_{cx}}\right)} + \dfrac{\left(\dfrac{\tau_d}{\tau_c}\right)^2}{1 - \left(\dfrac{\sigma_{dx}}{\sigma_{cx}}\right)} \leq 1$	

Symbols

σ_d = design compressive stress, *see* 4.1.3
σ_c = critical compressive buckling stress, in N/mm^2, for uniaxial compressive load acting independently, *see* 4.3.5
σ_{dx} = design compressive stress in x direction
σ_{dy} = design compressive stress in the y direction
σ_{cx} = critical compressive buckling stress in x direction, *see* 4.3.5
σ_{cy} = critical compressive buckling stress in y direction, *see* 4.3.5
λ_σ = buckling factor of safety for compressive stresses, *see* 4.3.4
λ_τ = buckling factor of safety for shear stresses, *see* 4.3.4
τ_d = design shear stress, in N/mm^2
τ_c = critical shear buckling stress, in N/mm^2, acting independently, *see* 4.3.5
A_R = *see* 4.2.1

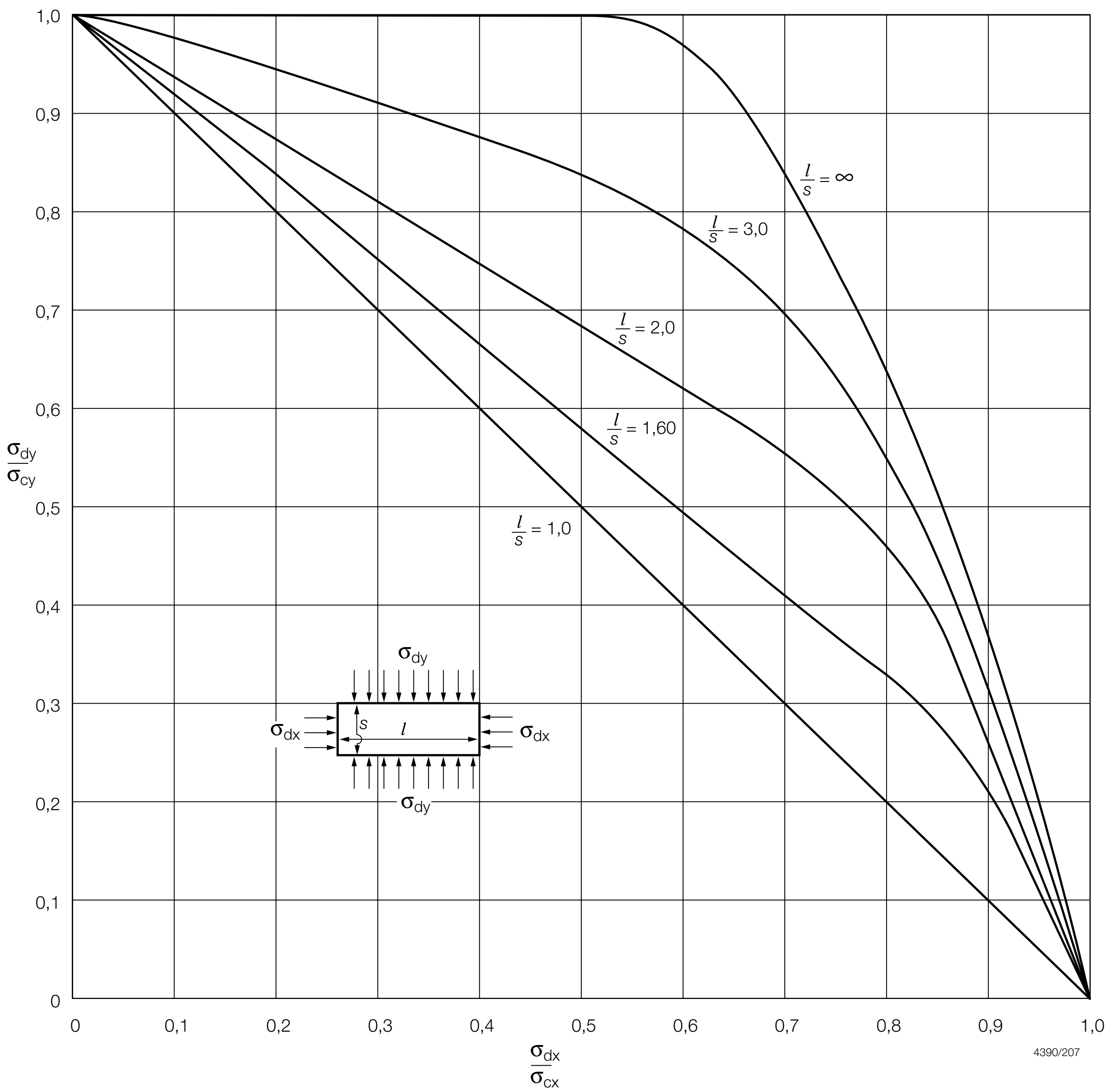


Fig. 7.4.3
Interaction limiting stress curves of G for plate panels subject to bi-axial compression, *see* Table 7.4.2(c)

Table 7.4.3 Buckling stress of secondary stiffeners (*see continuation*)

Mode	Elastic buckling stress, N/mm^2	Critical buckling stress, N/mm^2 *see* Note
(a) Overall buckling (perpendicular to plane of plating without rotation of cross-section)	$\sigma_{e(a)} = C_f\, 0{,}001\, E \dfrac{I_a}{A_{te}\, l_e^2}$	$\sigma_{c(a)}$
(b) Torsional buckling	$\sigma_{e(t)} = \dfrac{0{,}001 E\, I_w}{I_p\, l_e^2}\left(m^2 + \dfrac{K}{m^2}\right) + 0{,}385 E \dfrac{I_t}{I_p}$	$\sigma_{c(t)}$
(c) Web buckling (excluding flat bar stiffeners)	$\sigma_{e(w)} = 3{,}8\, E \left(\dfrac{t_w}{d_w}\right)^2$	$\sigma_{c(w)}$
(d) Flange buckling	$\sigma_{e(f)} = 0{,}39\, E \left(\dfrac{t_f}{b_f}\right)^2$	$\sigma_{c(f)}$

The critical buckling stresses are to be derived from the elastic buckling stresses as follows:

$$\sigma_c = \sigma_e \text{ when } \sigma_e < \frac{\sigma_a}{2}$$

$$= \sigma_a \left(1 - \frac{\sigma_a}{4\sigma_e}\right) \text{ when } \sigma_e \geq \frac{\sigma_a}{2}$$

Symbols

d_w = web depth, in mm, (excluding flange thickness for rolled sections), *see* Fig. 7.4.4
t_w = web thickness, in mm
b_f = flange width, in mm (including web thickness)
t_f = flange thickness, in mm. For bulb plates, the mean thickness of the bulb may be used, *see* Fig. 7.4.4
l_e = effective span length of stiffener, in metres
C_f = end constraint factor
= 1 where both ends are pinned
= 2 where one end pinned and the other end fixed
= 4 where both ends are fixed
E = Youngs Modulus of elasticity of the material, in N/mm^2
I_a = moment of inertia, in cm^4, of longitudinal, including attached plating of effective width b_{eb}, *see* Note
t_p and σ_a are given in 4.2.1
A_{te} and b_{eb} are given in 4.2.1

NOTE
For stiffeners attached to plating which buckles elastically, *see* 4.5, the effective width of plating is to be taken as b_{eu}.

Table 7.4.3 Buckling stress of secondary stiffeners (*conclusion*)

I_t = St.Venant's moment of inertia, in cm^4, of longitudinal (without attached plating)

$= \dfrac{d_w t_w^3}{3} 10^{-4}$ for flat bars

$= \dfrac{1}{3}\left[d_w t_w^3 + b_f t_f^3 \left(1 - \dfrac{0{,}63 t_f}{b_f}\right)\right] 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_p = polar moment of inertia, in cm^4, of profile about connection of stiffener to plating

$= \dfrac{d_w^3 t_w}{3} 10^{-4}$ for flat bars

$= \left(\dfrac{d_w^3 t_w}{3} + d_w^2 b_f t_f\right) 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_w = sectional moment of inertia, in cm^6, of profile and connection of stiffener to plating

$= \dfrac{d_w^3 t_w^3}{36} 10^{-6}$ for flat bars

$= \dfrac{t_f b_f^3 d_w^2}{12} 10^{-6}$ for 'Tee' profiles

$= \dfrac{b_f^3 d_w^2}{12 (b_f + d_w)^2} (t_f (b_f^2 + 2b_f d_w + 4d_w^2) + 3t_w b_f d_w) 10^{-6}$ for '*L*' profiles, rolled angles and bulb plates

C = spring stiffness exerted by supporting plate panel

$$= \frac{k_p E t_p^3}{3b\left(1 + \dfrac{1{,}33 k_p d_w t_p^3}{b t_w^3}\right)}$$

k_p = $1 - \eta_p$, and is not to be taken as less than zero. For built-up profiles, rolled angles and bulb plates, k_p need not be taken less than 0,1

$\eta_p = \dfrac{\sigma_d}{\sigma_{ep}}$

σ_{ep} = elastic critical buckling stress, in N/mm^2, of the supporting plate derived from Table 7.4.1

m is determined as follows; e.g. $m = 2$ for $K = 25$

K	0 to 4	4 to 36	36 to 144	144 to 400	400 to 900	900 to 1764	$(m-1)^2 m^2$ to $m^2 (m+1)^2$
m	1	2	3	4	5	6	m

$K = \dfrac{1{,}03 C S^4}{E I_w} 10^4$

σ_d is the design stress, in N/mm^2
all other symbols are as defined in 4.2.1

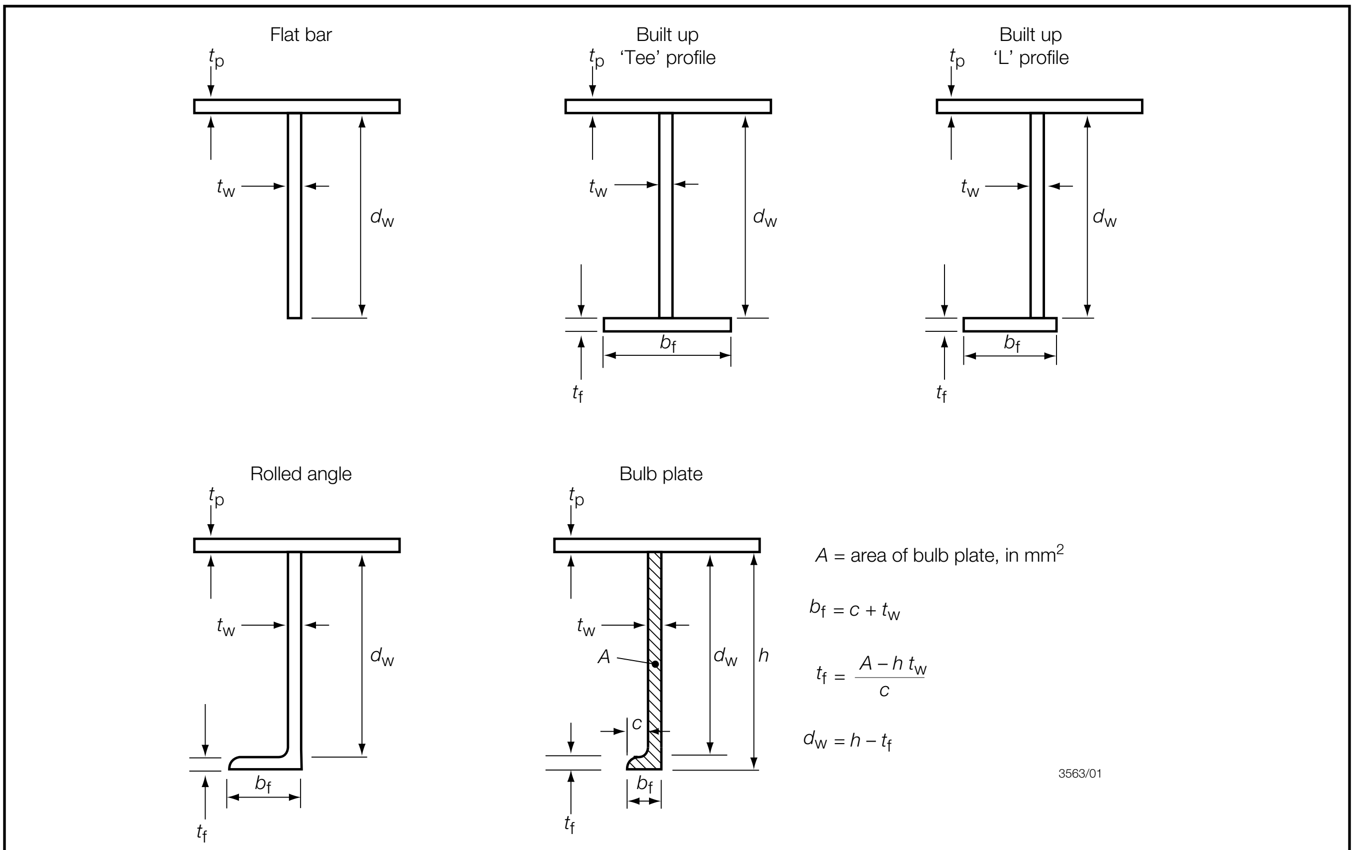


Fig. 7.4.4 Dimensions of longitudinals

Table 7.4.4 Buckling factor of safety

Structural item	Buckling factor of safety (2) Compressive stresses, λ_σ	Buckling factor of safety (3) Shear stresses, λ_τ
Bottom shell plating	1,0	–
Inner bottom plating	1,0	–
Deck plating	1,0	–
Side shell plating	1,0	1,1
Longitudinal bulkhead plating	1,0	1,1
Double bottom girders	1,0	1,1
Longitudinal girders	1,0	1,1
Superstructures/deckhouses (partially longitudinally effective)	1,0	–
Longitudinal secondary stiffeners	1,1(1)	–
Girder and floor web plating subject to local loads	1,1	1,2

NOTES
1. The buckling factor of safety for stiffeners attached to plating which is allowed to buckle in the elastic mode due to the applied loads is to be taken as 1,25, *see also* 4.5.
2. Buckling factor of safety to be applied to the compressive stress due to global longitudinal stresses.
3. Buckling factor of safety to be applied to the shear stress.

■ *Section 5* **Vibration control**

5.1 General

5.1.1 Natural frequencies are to be investigated for local unstiffened and stiffened panels expected to be exposed to excessive structural vibrations being induced from machinery, propulsion unit or other potential excitation sources.

5.1.2 Where the structural configurations are such that basic structural elements may be modelled individually the natural frequencies may be derived in accordance with 5.3, 5.4 and 5.5, as appropriate. Under other circumstances finite element analysis is to be employed to evaluate the vibration characteristics of the structure considered.

5.2 Frequency band

5.2.1 The natural frequency of panels is generally not to lie within a band of ±20 per cent of a significant excitation frequency.

5.3 Natural frequency of plate

5.3.1 The natural frequency of a clamped plate in air is given by the following:

$$f_{air} = 5{,}544 \frac{t_p}{ab} \sqrt{\left(\frac{a}{b}\right)^2 + \left(\frac{b}{a}\right)^2 + 0{,}6045} \quad \text{Hz}$$

where

a = panel length, in metres
b = panel breadth, in metres
t_p = panel thickness, in mm.

5.4 Natural frequency of plate stiffener

5.4.1 The natural frequency of a plate stiffener in air is given by the following:

$$f_{air,i} = \frac{K_i}{2\pi L_b^2} \sqrt{\frac{E\,I}{m\left(1 + \dfrac{\pi^2 E\,I}{L_b^2\, GA}\right)}} \quad \text{Hz}$$

where

$E\,I$ = flexural rigidity of plate stiffener combination, in Nm^2
GA = shear rigidity of plate stiffener combination, in N
L_b = beam length, in metres
m = mass per unit length of the stiffener and associated plating, in kg/m
K_i = constant where i refers to the mode of vibration as given in Table 7.5.1.

Table 7.5.1 Vibration mode constant K_i

Mode	1	2	3	4	5
K_i	22,40	61,70	121,0	200,0	299,0

5.5 Effect of submergence

5.5.1 To obtain the frequency, f_{water}, of a plate with one side exposed to air and the other side exposed to a liquid, the frequency calculated in air, f_{air}, may be modified by the following formula:

$$f_{water} = \psi\, f_{air}$$

where

$$\psi = \sqrt{\frac{\kappa_p}{\kappa_p + \dfrac{\rho_l}{\rho_p}}}$$

ρ_l = density of the liquid, in kg/m^3
ρ_p = density of the plate, in kg/m^3

$$\kappa_p = \frac{\pi\, t_p}{1000 a\, b} \sqrt{a^2 + b^2}$$

where

a, b and t_p are as defined in 5.3.1.

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HULL CONSTRUCTION IN COMPOSITE

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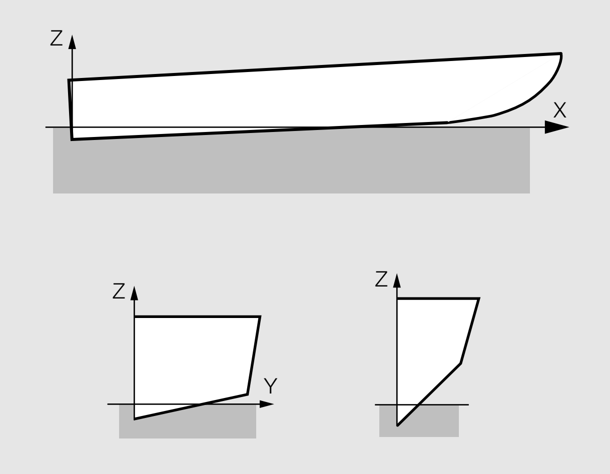
PART 8

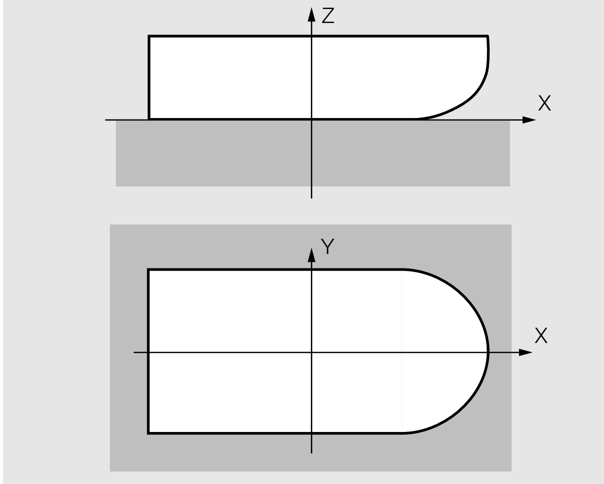
Lloyd's Register

DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

PLANING CRAFT



HOVERCRAFT



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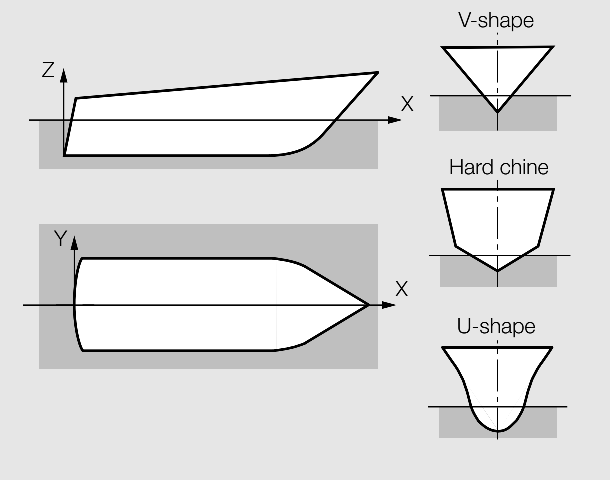

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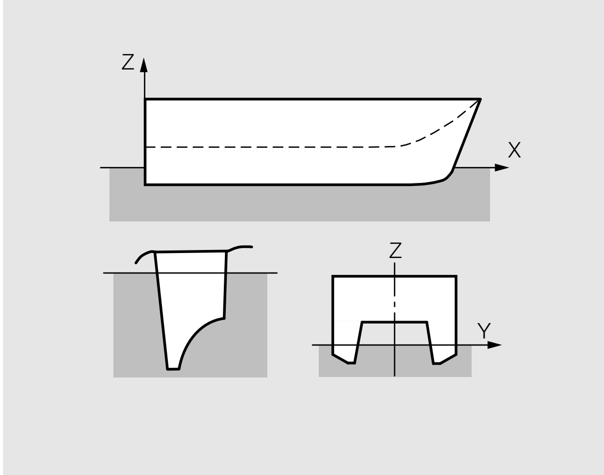

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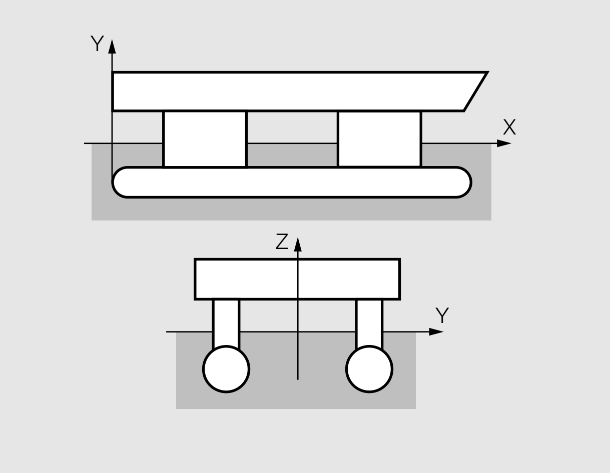
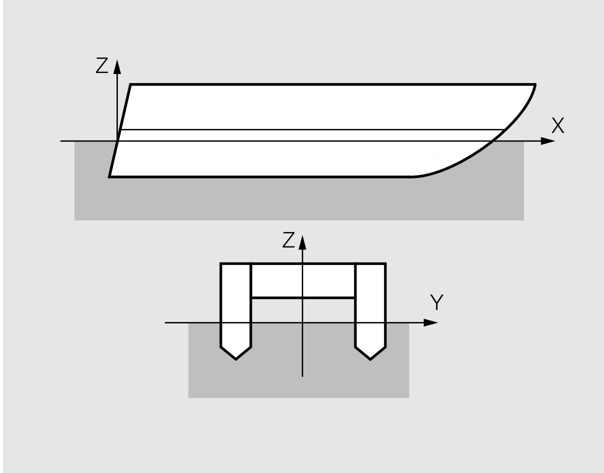
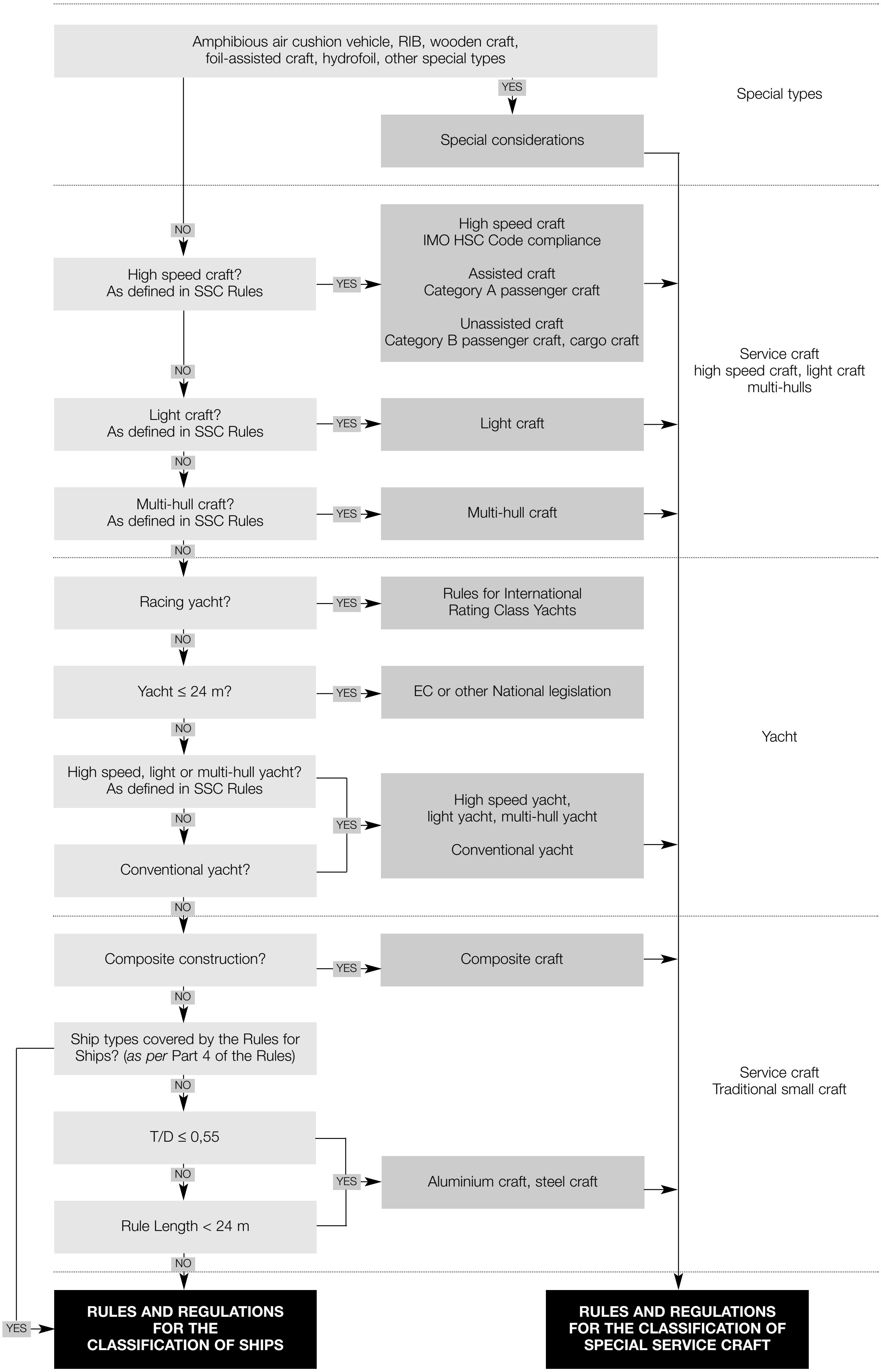


CATAMARAN



DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



Chapter Contents **Part 8**

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Section 1 Application

1.1 General

1.1.1 The Rules are applicable to mono and multi-hull craft of normal form, proportions and speed. Although the Rules are, in general, for fibre reinforced composite craft of laminated construction, other materials for use in hull construction will be specially considered on the basis of the Rules.

1.1.2 The Rules provide for craft of both single and sandwich skin construction.

1.2 Interpretation

1.2.1 The interpretation of the Rules is the sole responsibility and at the sole discretion of Lloyd's Register (hereinafter referred to as 'LR'). Where there is any doubt regarding the interpretation of the Rules it is the Builder's and/or designer's responsibility to obtain clarification from LR prior to submission of plans and data for appraisal.

1.2.2 Where applicable, the Rules take into account unified requirements and interpretations established by the International Association of Classification Societies (IACS).

1.2.3 Attention is drawn to the fact that Codes of Practice issued by IMO or other applicable National Authorities may contain requirements which are outside classification as defined in the Rules.

1.3 Equivalents

1.3.1 Alternative scantlings and arrangements may be accepted as equivalent to the Rule requirements. Details of such proposals are to be submitted for consideration in accordance with Pt 3, Ch 1,3.

1.4 Symbols and definitions

1.4.1 The symbols and definitions for use throughout this Part are as defined within the appropriate Chapters and Sections.

Section 2 General requirements

2.1 General

2.1.1 Specific limitations regarding the application of the Rules are indicated in the various Chapters for differing types of craft.

2.2 Aesthetics

2.2.1 LR is not concerned with the general arrangement, layout and appearance of the craft; the responsibility for such matters remains with the Builders and/or designers to ensure that the agreed specification is complied with. LR is however concerned with the quality of workmanship, and in this respect the acceptance criteria as required by the Rules are to be complied with.

2.3 Constructional configuration

2.3.1 The Rules provide for the basic structural configurations for both single and multi-deck mono and multi-hull craft with single or double bottom arrangements. The structural configuration may also include a single or multiple arrangement of cargo hatch openings and side tanks.

2.3.2 The Rules provide for longitudinal and transverse framing systems.

2.3.3 Novel or other types of framing systems will be considered on the basis of the Rules.

2.4 Plans to be submitted

2.4.1 Plans covering the following items are to be submitted:

- Midship sections showing longitudinal and transverse material.
- Profile and decks.
- Deck hatches.
- Bridging structure.
- Shell expansion.
- Laminate schedule.
- Oiltight and watertight bulkheads.
- Propeller brackets.
- Integral tanks.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Doors, hatches, windows and portlights.
- Deckhouses and superstructures.
- Sternframe.
- Rudder, stock and tiller.
- Anchoring and mooring equipment.
- Loading manuals, preliminary and final (where applicable).
- Ice strengthening.
- Welding (where applicable).
- Hull penetration plans.

- Support structure for masts, derrick posts or cranes.
- Bilge keels showing connections and detail design.
- Chain-plates.

2.4.2 The following supporting documents are to be submitted:
- General arrangement.
- Capacity plan.
- Lines plan or equivalent.
- Dry-docking plan.
- Towing and mooring arrangements.
- Sail/rigging plan, indicating loadings (as applicable to sailing craft).

2.4.3 The following supporting calculations are to be submitted, *see also* 2.7:
- Equipment Number.
- Hull girder still water and dynamic wave bending moment and shear force as applicable.
- Midship section stiffness.
- Structural items in the aft end, midship and fore end regions of the craft.
- Preliminary freeboard calculation.

2.5 Materials data sheet

2.5.1 Details of all the approved and accepted plastics materials, as required by the Rules, are to be submitted on LR's Reinforced Plastic Structures Materials Data Sheet (Form 2075) with the initial submission of plans. Reference is to be made to Ch 2,2. The types and quantities of curing systems identified on the Materials Data Sheet are to be those recommended by the resin manufacturer for the approved resin systems.

2.5.2 When specifying materials, the exact manufacturer's type designation, identification and reference numbers are to be quoted.

2.5.3 All sandwich core materials are to be of a type acceptable to LR and are to be clearly identified together with any core bonding adhesive to be used.

2.5.4 Fibre contents by weight for each type of reinforcement are to be reported.

2.5.5 All relevant post curing data is to be documented on the Materials Data Sheet.

2.6 Novel features

2.6.1 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of LR, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the appropriate *Register Book*.

2.7 Direct calculations

2.7.1 Direct calculations may be specifically required by the Rules and may be required for craft having novel design features or in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of the designers and make recommendations in regard to suitability of any required model tests.

2.7.2 Where direct calculations are proposed then the requirements of Pt 3, Ch 1,2 are, in general, to be complied with.

2.8 Exceptions

2.8.1 Craft of unusual form, proportions or speed, intended for the carriage of special cargoes, not covered specifically by the Rules, will receive individual consideration based on the general requirements of the Rules.

2.9 Advisory services

2.9.1 The Rules do not cover certain technical characteristics, such as stability, except as mentioned in Pt 1, Ch 2,1.1.11, 1.1.13 and 1.1.14, trim, vibration, docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

■ *Section 1* General requirements

1.1 General

1.1.1 The Rules are applicable to craft generally constructed of fibre reinforced plastic in accordance with 2.1.1.

1.1.2 All construction is to be carried out using materials and techniques approved or accepted by Lloyd's Register (hereinafter referred to as 'LR'). Where non-approved or non-accepted materials or production techniques are proposed, it is the responsibility of the Builder and manufacturer to obtain the necessary approval or acceptance and demonstrate their equivalence on the basis of the Rules.

1.1.3 It is the Builder's responsibility to ensure that all materials are used in accordance with the manufacturer's instructions.

1.2 Definitions

1.2.1 Definitions for use throughout this Chapter are as indicated in the appropriate Sections.

1.3 Symbols

1.3.1 Symbols for use throughout this Chapter are as indicated in the appropriate Sections.

1.4 Builder's facilities

1.4.1 The buildings used for production and storage are to be of suitable construction and equipped to provide the required environment, and are to comply with any local or National Authority requirements.

1.4.2 Workshops and equipment are to be in accordance with good manufacturing practice and are to be to the satisfaction of the Surveyor.

1.4.3 The Surveyor is to be allowed unrestricted access during working hours to such parts of the Builder's establishment as may be necessary to ensure that the requirements of the Rules are being complied with.

1.5 Works inspection

1.5.1 Prior to the commencement of production the facilities are to be inspected to the satisfaction of the attending Surveyor. This is to include evidence that the mandatory minimum quality control requirements as outlined in 1.6 and Ch 14,5 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), are fulfilled.

1.5.2 The Surveyor is to be satisfied that the Builder has the organisation and capability to mould craft to the standards required by the Rules.

1.5.3 The Builder is to rectify any deficiencies to the Surveyor's satisfaction prior to the commencement of production.

1.5.4 The validity of the acceptance of the Builder's works for moulding craft under LR survey is subject to an annual QC audit and monitoring by the attending Surveyor. Where there is a break in the continuity of moulding under LR survey, the facilities will in general, be subject to an additional inspection prior to any recommencement of any moulding carried out under LR survey.

1.5.5 For acceptance the survey is to include procedures covering the Builder's management, organisation and quality systems.

1.6 Quality control

1.6.1 The Builder's mandatory quality systems for composite construction, will be subject to inspection and audit, and are to be in accordance with the requirements of one of the following:

(a) Quality Assurance System in accordance with an International or National Standard (i.e. ISO 9000 and BS ENISO 9001) with assessment and certification carried out by a nationally accredited body and must reflect the minimum quality control requirements under (c) being complied with.

(b) LR's *Quality Assurance Scheme for the Construction of Special Service Craft*.

(c) LR's locally accepted Quality Control System – The Builder is implementing a documented Quality Control System which controls the activities as indicated below, *see also* Ch 14,5 of the Rules for Materials:
  - (i) Receipt storage and issue of materials, equipment, etc.
  - (ii) Moulding shop.
  - (iii) Care and preparation of mould tools, etc.
  - (iv) Lay-up process control.
  - (v) Inspection of FRP mouldings on release.
  - (vi) Installation of machinery and essential systems.
  - (vii) Fitting-out.
  - (viii) Tests and trials.
  - (ix) Plans and document control.
  - (x) Records.

1.6.2 LR's involvement is only in that part of the system which controls the standards required to meet the classification requirements.

1.6.3 The mandatory 'documented' quality control system, in general, requires the Builder to have written down procedures that describe clearly and unambiguously how each of the above activities is carried out, when it is carried out and by whom. These procedures will form part of the system manual which is also to contain a statement of management policy, organisation chart and statements of responsibilities. The manual is to be controlled covering formal issue and revision.

1.7 Moulding shop

1.7.1 Where the conventional hand lay-up or spray lay-up processes are used, an even shop temperature of not less than 16°C, and, in general, of not more than 25°C, is to be maintained throughout the moulding area during the lay-up and curing periods. Where the temperature exceeds 25°C, special consideration is to be given to the resin system.

1.7.2 Where moulding processes other than those in 1.7.1 are to be used, the moulding shop temperature will be subject to individual consideration in conjunction with the written recommendations of the manufacturers of the materials.

1.7.3 The relative humidity in the moulding shop is to be kept below 70 per cent, taking into account the dew point, thus avoiding moisture condensation on moulds and materials.

1.7.4 Sufficient temperature and humidity monitoring equipment is to be provided and detailed records are to be kept in accordance with the quality control system.

1.7.5 It is the responsibility of the Builder to ensure that the ventilation and working conditions, together with discharges into the atmosphere, are such that levels of substances are within the limits specified in any pertinent National or International legislation.

1.7.6 The working areas are to be adequately illuminated. Precautions are to be taken to avoid any effects on the resin cure due to direct sunlight or artificial lighting.

1.8 Storage areas

1.8.1 The resins are to be stored under dry, well-ventilated conditions, in accordance with the manufacturer's recommendations.

1.8.2 Where resin tanks or drums are stored outdoors it is the Builder's responsibility to ensure that the resin manufacturer's storage conditions are complied with.

1.8.3 Where the temperature for materials storage drops below that of the moulding shop i.e. minimum 16°C, the materials are to be pre-conditioned to the moulding shop temperature prior to use.

1.8.4 Curing agents are to be stored separately under clean, dry and well-ventilated conditions in accordance with the manufacturer's recommendations and any local or National legislation.

1.8.5 Fillers and additives are to be stored in closed containers that are impervious to dust and moisture.

1.8.6 Reinforcements are to be stored under dust-free and dry conditions.

1.9 Mould construction

1.9.1 Moulds are to be constructed of a suitable material and are to be adequately stiffened to maintain their overall shape and fairness of form.

1.9.2 The materials used in the construction of moulds are not to affect the resin cure.

1.9.3 The finish on a mould is to be such that the mouldings produced are suitable for the purpose intended. The resultant aesthetic appearance of the moulding is strictly a matter between the moulder and the Owner.

1.9.4 Where multiple section moulds are used, the sections are to be carefully aligned to the attending Surveyor's satisfaction prior to moulding. Mismatch between mould sections is to be eliminated.

1.9.5 Where metallic moulds are used, welding is to be minimised to avoid distortion of panels.

1.9.6 The release agent is to be of a type recommended by the resin manufacturer and is not to affect the cure of the resin.

1.9.7 Prior to use all moulds are to be conditioned to the workshop temperature.

1.10 Materials handling

1.10.1 The arrangements for the receipt, verification against certificates of conformity and subsequent handling of materials are to be covered by the Builder's quality control procedures such that the materials do not suffer contamination or degradation and bear adequate identification at all times; *see* Ch 14,3 of the Rules for Materials. Storage is to be arranged such that materials are used by batch wherever possible, in order of receipt. Materials are not to be used after the manufacturer's date of expiry, except with the prior agreement of LR and new certificates of conformity being obtained from the material manufacturer. Details of the new certificates of conformity are to be entered into the quality control system.

1.10.2 Where materials are found to be non-conforming they are to be rejected in accordance with the Builder's quality control procedure.

1.10.3 All non-conforming materials are to be segregated in their storage areas and marked accordingly.

1.10.4 Resin/catalyst pumps and spray equipment are to be operated in accordance with the manufacturers instructions. Maintenance and calibration of the mix ratio is to be carried out according to written procedures.

1.11 Faults

1.11.1 All faults are to be classified according to their severity and recorded, together with the remedial action taken, under the requirements of the quality control systems, the documentation being subject to review at the Periodical Survey.

1.11.2 Production faults are to be brought to the attention of the attending Surveyor and a rectification scheme agreed. Deviations from the approved plans are to be to the satisfaction of the attending Surveyor.

1.12 Inspection

1.12.1 It is the Builder's responsibility to carry out the required inspections in accordance with the accepted quality control system.

1.12.2 The Surveyor will monitor the Builder's quality control records and carry out inspections of work in progress during his periodical visits.

1.12.3 During inspections all deviations are to be dealt with under the Builder's agreed quality procedures, *see* 1.6.3.

1.13 Acceptance criteria

1.13.1 Classification is dependent upon the work being carried out in accordance with the approved plans and the requirements of an accepted quality system.

1.13.2 The workmanship is to be to the satisfaction of the attending Surveyor. This will include the verification of the quality control documentation and the remedial action associated with all defects and deficiencies recorded.

1.13.3 Proposed deviations from the approved plans are subject to LR approval. An amended plan is to be submitted to the plan appraisal office, prior to any such changes being introduced.

1.14 Repair

1.14.1 Minor repairs are to be agreed with the attending Surveyor prior to being carried out. The Builder is to incorporate details of the agreed repair procedures in the quality control system in accordance with 1.6.3.

1.14.2 Written details of proposed structural repairs are to be submitted to the Plan Approval Office for approval prior to introduction.

1.15 Scaffolding

1.15.1 Scaffolding/platform arrangements are to be provided to permit adequate access for production and inspection purposes. Such arrangements are to conform to National Authority requirements and are not, in general, to be connected to the moulding or impinge on the mould surface.

1.16 Access

1.16.1 The attending Surveyor is to be permitted reasonable access to all areas of the Builder's premises during normal working hours. Scaffolding/platform arrangements are to be made available in accordance with 1.15.

1.17 Lifting arrangements

1.17.1 Lifting arrangements are to be designed such that mouldings are subjected to minimal distortion and unnecessary stressing. Mouldings are to be adequately supported to avoid distortion during final cure.

■ *Section 2* Materials

2.1 General

2.1.1 The Rules are applicable to craft generally constructed of fibre reinforced plastic (typically with unsaturated polyester resin), using hand lay-up, mechanical deposition, contact moulding techniques or vacuum assisted techniques. Construction may be either single-skin or sandwich construction, or a combination of both.

2.1.2 Other materials (i.e. non-FRP materials) are to be of good quality, suitable for the purpose intended and, where applicable, are to comply with LR's requirements appropriate to the material. Details of these materials are to be stated on the relevant construction plans. Where these materials are attached to, or encapsulated within, the plastics construction, the material is not to affect adversely the cure of the plastics materials.

2.1.3 Where moulding techniques and methods of construction differing from those given in Section 3 are proposed, details are to be submitted for consideration by LR.

2.2 Resin system

2.2.1 The resins used are to be of a type that has been approved by LR for marine construction purposes. Samples of the resin batches being used in the construction may be taken for limited quality control examination at the discretion of the Surveyor, *see* Ch 14,5 of the Rules for Materials.

2.2.2 The cure procedure for the resin system is to be that recommended by the resin manufacturer for the particular application, so that the resin will cure in the required time, in accordance with the approved cure schedule.

2.2.3 Wax additives are only to be added by the resin manufacturer in accordance with the agreed procedure and tested accordingly. The base resin is to be of an approved type.

2.2.4 Where a resin contains an ingredient that can settle within the resin system, it is the Builder's responsibility to ensure that the resin manufacturer's recommendations regarding mixing and conditioning are complied with prior to use.

2.3 Compliant resins

2.3.1 Compliant resins for structural applications are to be of types accepted by LR, *see* Ch14,2.15 of the Rules for Materials, and are to be used strictly in accordance with the manufacturer's recommendations.

2.3.2 Details of the compliant resin to be used in the construction are to be included on the Material Data Sheet at the initial stages of plan approval. The plans submitted for approval are to identify which compliant resins are used in different applications. Surface preparations and over-bonding are also to be identified on the submitted plans.

2.3.3 Proposals for the use of structural filleting applications using compliant resin are to be submitted in detail. Such proposals will be subject to individual consideration.

2.3.4 The acceptance of the use of structural fillets of compliant resins in place of boundary bonding angle laminates required by Ch 3,1.18, will be subject to the designer/Builder providing the necessary information and test results to demonstrate equivalence with the Rule requirement for boundary bonding angle laminates.

2.3.5 Air inclusions that may affect the structural efficiency of the joint are to be avoided.

2.4 Resin storage

2.4.1 Bulk storage of resin is to be arranged in accordance with the resin manufacturer's recommendations in suitably adapted and insulated tanks. Tanks and pipes are to be periodically flushed in accordance with the resin manufacturer's recommendations. A ready use store is to be provided where appropriate.

2.5 Gel coats, tie coats and water barriers

2.5.1 Gel coats based on orthophthalic polyester resin systems are not acceptable. All gel coats are to be used strictly in accordance with the manufacturer's recommendations. The curing system is to be in accordance with 2.2.2.

2.5.2 Where pigments are to be added reference is to be made to 2.6. Where pigments are added by the Builder, the gel coat is to be allowed to stand for sufficient time to permit entrapped air to be released. The method of mixing is to be carried out strictly in accordance with the resin and pigment manufacturer's instructions.

2.5.3 Where the temperature of the gel coat resin is below that of the workshop, the gel coat resin is to be conditioned to attain the workshop temperature prior to use.

2.5.4 Where the inspection of the mould is an agreed hold point, required by the quality plan, the mould is to be inspected by the attending Surveyor prior to gel coating. The Surveyor may also require to witness the initial application of the gel coat, *see also* 3.3.

2.5.5 Where a gel coat is not used, details of the proposed water barrier are to be submitted for consideration.

2.5.6 Where a painted finish is to be adopted in place of a gel coat a suitable tie coat may be required in accordance with the paint manufacturer's recommendations.

2.5.7 Where the hull is of sandwich construction built on a male plug mould, the water barrier on the outer surface of the hull will be specially considered.

2.6 Curing systems

2.6.1 Curing systems are to be in accordance with 2.2.2 and are to be fully compatible with the resins and reinforcements to be used.

2.6.2 For polyester and vinylester resins the level of catalyst and accelerator are to be as recommended by the manufacturer to ensure full polymerisation of the resin. In general, the rate of gelation is to be controlled by the amount of accelerator added to the resin. The amount of catalyst is not to be less than one per cent, by weight, of the base resin.

2.7 Gelation time

2.7.1 The gelation time is to be suitable for the proposed application such that full wet-out of the reinforcement can be obtained without unnecessary drainage on vertical surfaces or excessive loss of the monomer.

2.7.2 The gelation time quoted on the Material Data Sheet is to be the typical gelation time for a laminate as laid in the mould, i.e. the working life of the resin.

2.7.3 The gelation time may need to be varied to suit changing ambient workshop temperatures. For polyester and vinylester resins this is, in general, to be adjusted by variation of the accelerator and not by variation of the catalyst.

2.7.4 All resins are to be mixed in accordance with the resin manufacturer's recommendations.

2.8 Colour pigments

2.8.1 The types of pigment used are to be such that the final cure of the resin is not affected.

2.8.2 The pigment may be added to the resin by either the resin manufacturer or the moulder, and when added by the moulder it is to be as a paste dispersal in the same or compatible resin. Pre-pigmented gel coats are recommended. Where pigments are added by the Builder thorough mixing is essential to avoid striations. *See also* 2.2.4 and 2.3.2.

2.8.3 The amount and type of pigment added is not to exceed that recommended by the resin manufacturer for a satisfactory depth of colour. Proposals to use amounts of pigment solids in excess of five per cent, by weight of the base resin, will be subject to individual approval and testing.

2.8.4 It is recommended that pigments are not to be added to the gel coat or laminating resins used in the under-water portion of the hull laminate or in laminates forming the boundaries of oil fuel and water tanks.

2.8.5 The addition of pigments is not to unduly affect the gelation time of the resin system or the physical properties of the gel coat layer of the laminate produced. The resin and/or pigment manufacturer's written confirmation in this respect is to be obtained and recorded in the Builder's quality control documentation.

2.8.6 The aesthetic appearance of mouldings is strictly a matter between the moulder and the Owner.

2.9 Fillers

2.9.1 All fillers added by a Builder are to be of the dispersed type. The amount of filler that may be added to an approved resin is to be that recommended by the resin manufacturer and is not to alter significantly the viscosity of the resin nor is it to affect the overall strength properties of the laminate. Recommendations by the resin manufacturer to adopt amounts of fillers in excess of 13 per cent by weight of the base resin will be subject to individual approval and testing.

2.9.2 Pigments, thixotropes and fire retardant additives are to be considered as fillers in the calculation of total filler content.

2.9.3 Fillers are to be carefully and thoroughly mixed into the base resin that is then to be allowed to stand to ensure that entrapped air is released. The resin manufacturer's recommendations regarding the method of mixing are to be followed.

2.9.4 Fillers are not to be used in the structural laminates forming the boundaries of oil fuel and water tanks.

2.9.5 Details of all fillers and fire retardant additives are to be included on the Material Data Sheet at the initial stages of plan appraisal.

2.9.6 The amount of fire retardant additives may be in excess of that indicated in 2.9.1 provided that due account is taken of the reduced mechanical properties when determining scantlings in accordance with the Rules.

2.10 Fire retardant additives

2.10.1 The attention of Owners and Builders is drawn to the additional statutory regulations regarding fire safety that may be imposed by the National Authority of the country in which the craft is to be registered or the Governments of the states to be visited.

2.10.2 For requirements regarding fire safety, *see* Part 17.

2.10.3 Where laminates are required to have fire retardant or restricting properties, details of the proposals are to be submitted for approval. Where additives to the resin system are used, the type and quantity are to be as recommended by the resin manufacturer. Test results of independently tested fire retardant and fire restricting materials are to be submitted for design purposes.

2.10.4 All fire retardant resin systems are to be used strictly in accordance with the resin manufacturer's recommendations.

2.10.5 The use of fire retardant and fire restricting materials in craft required to comply with statutory require-ments will be subject to the individual approval of the National Authority of the country in which the craft is to be registered, or LR where authorised to undertake this work on behalf of the National Authority.

2.11 Fibre reinforcements

2.11.1 All fibre reinforcements are to be of a type approved by LR.

2.11.2 All reinforcements are to be stored strictly in accordance with the manufacturer's recommendations. Rolls of reinforcement are to remain in their original packaging to minimise contamination. The quality control documentation is to provide traceability of all reinforcements using the manufacturer's batch numbers.

2.11.3 The materials are to be free from imperfections, discolouration, foreign matter and other defects.

2.11.4 Pre-impregnated reinforcements are to be suitably stored in an approved area. Detailed storage records are to be maintained as part of the quality control documentation.

2.12 Surfacing materials

2.12.1 Lightweight surfacing materials for reinforcing resin rich surfaces are to be compatible with the resin being used. Details of the materials and the fibre contents, by weight, are to be included on the Materials Data Sheet (Form 2075).

2.12.2 Where peel ply materials are to be used, the finish is to be such that, after removal, it does not interfere with any subsequent bonding processes.

2.13 Core materials

2.13.1 Core materials for sandwich construction are to be approved by LR, *see* Ch 14,2 of the Rules for Materials.

2.13.2 All core materials are to be used in accordance with the manufacturer's application procedure, a copy of which is to be submitted for information, with the relevant construction plans of the craft. A second copy is to be incorporated into the quality control documentation.

2.13.3 Rigid expanded foam plastics are to:
(a) be of closed-cell types and impervious to water, fuel and oils;
(b) have good ageing stability;
(c) be compatible with the resin system;
(d) have good strength retention at 60°C;
(e) have characteristics and mechanical properties of not less than those indicated in Table 2.2.1; and
(f) if manufactured into formable sheets of small blocks, the open weave backing material and adhesive are to be compatible and soluble, respectively, with the laminating resin.

2.13.4 Balsa wood is to:
(a) be end grained;
(b) have been chemically treated against fungal and insect attack and kiln dried shortly after felling;
(c) have been sterilised;
(d) have been homogenised;
(e) have an average moisture content of 12 per cent;
(f) have characteristics and mechanical properties of not less than those indicated in Table 2.2.2; and
(g) if manufactured into formable sheets of small blocks, the open weave backing material and adhesive are to be compatible and soluble, respectively, with the laminating resin.

2.13.5 Where necessary, foam core materials are to be conditioned in accordance with the manufacturer's recommendations. Conditioning at an elevated temperature, in excess of that which may be experienced in service, may be necessary to ensure the release of any entrapped residual gaseous blowing agents from the cells of the foam core.

2.13.6 Synthetic 'felt' type core materials are to be approved in accordance with Ch 14,2.10 of the Rules for Materials.

2.13.7 Other types of core materials will be individually considered, on the basis of these Rules in relation to their characteristics and intended application.

2.13.8 Balsa wood is to remain in protective packaging until required in production. Part packages are to be sealed to prevent the ingress of moisture.

2.14 Core bonding materials

2.14.1 Core bonding materials for structural applications are to be of types accepted by LR, and are to be used strictly in accordance with the manufacturer's instructions.

2.14.2 Details of the proposed core bonding paste to be used with the core material are to be indicated on the Materials Data Sheet and the appropriate construction plans.

Table 2.2.1 Minimum characteristics and mechanical properties of rigid expanded foams at 20°C

Material	Apparent density (kg/m^3)	Strength (N/mm^2)			Moduli of elasticity (N/mm^2)	
		Tensile	Compressive	Shear	Compressive	Shear
Polyurethane	96	0,85	0,60	0,50	17,20	8,50
Polyvinylchloride	60					

Table 2.2.2 Minimum characteristics and mechanical properties of end-grain balsa

Apparent density (kg/m^3)	Strength (N/mm^2)					Compressive modulus of elasticity (N/mm^2)		Shear modulus of elasticity (N/mm^2)
	Compressive		Tensile		Shear	Direction of stress		
	Direction of stress							
	Parallel to grain	Perpendicular to grain	Parallel to grain	Perpendicular to grain		Parallel to grain	Perpendicular to grain	
96	5,00	0,35	9,00	0,44	1,10	2300	35,20	105
144	10,60	0,57	14,60	0,70	1,64	3900	67,80	129
176	12,80	0,68	20,50	0,80	2,00	5300	89,60	145

2.14.3 The Builder is to demonstrate that a uniform thickness of bonding paste is obtained by use of notched trowels or comb gauges. For the use of bonding pastes, *see* 4.2.7.

2.15 Adhesives

2.15.1 Adhesives for structural applications are to be of types accepted by LR, *see* Ch 14,2.15 the Rules for Materials, and are to be used strictly in accordance with the manufacturer's recommendations.

2.15.2 The details of all structural adhesives are to be specified on the Materials Data Sheet and on the relevant construction plans submitted.

2.15.3 Details concerning the handling, mixing and application of adhesives are to form part of the Builder's production plan.

2.15.4 Particular attention is to be given to the surface preparation and cleanliness of the surfaces to be bonded.

2.15.5 Where excessive unevenness of the faying surfaces exists a suitable gap filling adhesive is to be used or local undulations removed by the application of additional reinforcements.

2.15.6 The Builder's quality plan is to identify the level of training required for personnel involved in the application of structural adhesives.

2.16 Materials for integrated structural members

2.16.1 Metallic materials, such as steel or aluminium alloys, used in the construction are to comply with the requirements of 2.1.2. Where structural members or components manufactured from these, or other materials, are to be encapsulated within or structurally bonded to laminates, the material is not to adversely affect the cure of the resin system. The surface area of the component that will be in contact with the resin is to be thoroughly cleaned, degreased and, where practicable, either shot blasted or abraded to provide a key.

2.16.2 Where metallic sections are to be bolted into a structure, the bolting requirements are to be determined by direct calculations that are to be submitted for consideration. Appropriate precautions against corrosion are to be taken.

2.16.3 Where plywood and timber members are to be used in structural applications and are to be laminated onto, or encapsulated within the laminate, the surface of the wood is to be suitably prepared and primed prior to laminating.

2.17 Plywood

2.17.1 Plywood, for structural applications, is to be of a high quality marine grade material approved by LR, *see* Ch 14,2.14 of the Rules for Materials. In general, the plywood is to be manufactured to a high standard of finish in accordance with ISO or other recognised standards and is to meet, or be equivalent to, the following general requirements:

(a) Have good quality face and core veneers of a durable hardwood species.
(b) The number of veneers is to be in accordance with Table 2.2.3.
(c) The veneers are to be bonded with a WBP (water and boil proof) type adhesive.
(d) Have a moisture content not exceeding 15 per cent.

Table 2.2.3 Number of veneers

Board thickness, mm	Minimum number of plies
up to 9	3
10 to 19	5
20 and above	7

2.17.2 Butts and seams are to be scarfed or butt strapped where necessary. The length of the scarf is to be not less than eight times the plywood thickness. The scarf is to be glued and, if made *in situ*, fitted with a backing strap of width not less than 10 times the panel thickness. The strap is to be glued and fastened with two rows of fastenings of the size given in Table 2.2.4 and spaced at approximately eight times the panel thickness.

2.17.3 Butt straps are to be of the width given in Table 2.2.4 and the same thickness as the panel. The strap is to be glued and double/treble fastened to the panel. Sizes of fastenings are given in Table 2.2.4.

2.17.4 For further information regarding plywood, *see* Ch 3,1.20.

2.18 Timber

2.18.1 The acceptance of timber in the construction will be subject to individual consideration depending upon the intended use and timber involved.

2.18.2 The timber is to be of good quality and properly seasoned. Timber is to be free from heart, sapwood, decay, insect attack, splits, shakes and other imperfections that would adversely affect the efficiency of the material. It is also to be generally free from knots, although an occasional sound intergrown knot would be acceptable.

2.18.3 The moisture content of timber for bonded or over-laminated applications using polyester or epoxy resins is, in general, to be nominally 15 per cent. Contents slightly greater than this value are recommended when resorcinol glues are used, and contents slightly lower than this value are required when phenolic or urea-formaldehyde resins are used.

2.18.4 For further information regarding timber, *see* Ch 3,1.19.

Table 2.2.4 Butt strap fastenings

Plywood thickness, mm	Breadth of butt strap, mm		Fastenings		
			Wood screws		Copper boat nails, gauge
			Gauge	Dia.,mm	
6 8 10 13 16	Double fastened	150 175 200 250 280	8 10 10 12 12	4,2 4,9 4,9 5,6 5,6	10 10 8 8 6
19 22 25	Treble fastened	330 355 380	14 14 16	6,3 6,3 7,0	6 3 3

NOTES
1. The gauge of wood screws given in the Table is British Standard Gauge, and that of copper boat nails is Imperial Standard Wire Gauge.
2. The diameter of the wood screw is the nominal diameter of the unthreaded shank.

2.19 Release agents

2.19.1 Release agents are to have no inhibiting effect on the gel coat resin and are to be those recommended by the resin manufacturer.

■ *Section 3* General construction process

3.1 General

3.1.1 Provision is made in this Section for the construction of craft built of fibre reinforced plastic using thermosetting materials. Craft built of fibre reinforced thermoplastic materials will be subject to individual consideration.

3.1.2 This Section contains the general Rule requirements to be complied with in the construction of fibre reinforced craft being built under survey. Where detailed requirements are not defined good boat building practices are to be applied.

3.1.3 Craft built of unusual materials or built using unusual techniques will be subject to individual consideration.

3.2 Resin preparation

3.2.1 Curing agents, fillers and pigments are to be added strictly in accordance with the resin manufacturer's recommendations.

3.2.2 Before decanting, all resins are to be thoroughly mixed, deaerated and conditioned to at shop temperature in accordance with the resin manufacturer's instructions.

3.2.3 All measuring equipment is to be certified and suitable for the quantity of material being measured. Valid certificates of calibration are to form part of the quality control documentation.

3.2.4 Where pumping/metering equipment is used it is to be maintained in accordance with the manufacturer's instructions, and a valid certificate of calibration accuracy is to be retained in the quality control documentation.

3.2.5 Quality control records are to be maintained to provide traceability and identification of the resin and all additives used in the resin system. Batch numbers are to be identified.

3.2.6 Any additive used as a production aid must be that recommended by the resin manufacturer and is not to alter the mechanical properties or the characteristics of the cured laminate.

3.3 Laminating

3.3.1 Production is to follow all necessary approved construction plans in accordance with the LR accepted quality plan.

3.3.2 Laminating is to be carried out by skilled operators, who are to be trained and qualified to the level required by the Builder's quality plan and are to be acceptable to LR.

3.3.3 Moulds are to be thoroughly cleaned, dried and allowed to attain the shop temperature before being treated with a suitable release system, *see also* 1.9.7.

3.3.4 The gel coat resin is to be applied by brush, roller or spraying equipment to give a uniform, nominal film thickness of 0,5 mm.

3.3.5 The period of exposure of the gel coat between gelation and the application of the first layer of reinforcement is, in general, to be as short as practicable. In no case is this to be longer than that recommended by the resin manufacturer for that particular resin system. Written confirmation of this is to be obtained and recorded in the Builder's quality control documentation.

3.3.6 Where a polyester or vinylester gel coat is used it is to be reinforced by a lightweight, powder bound reinforcement, generally not exceeding 300 g/m^2 in weight, applied at a high resin content to give a glass content, by weight, of not greater than 0,286. This reinforcement is to be consolidated by gentle rolling. Care is to be taken not to damage the gel coat. A surface tissue may be incorporated within the gel coat, the details of which are to be clearly stated in the laminate schedule.

3.3.7 All mouldings are to be manufactured from layers of reinforcement, laid in the approved sequence and orientation, each layer being thoroughly impregnated and consolidated to give the required fibre content, by weight, in accordance with the approved plans.

3.3.8 In composite laminates, containing multiple layers of woven reinforcement, woven reinforcement may be laid on woven reinforcement provided that the inter-laminar shear strength is not less than 13,8 N/mm^2; otherwise, a layer of random fibre reinforcement is to be laid alternately with the woven reinforcements.

3.3.9 Excessive exothermic heat generation caused by thick laminate construction is to be avoided. Where thick laminates are to be laid the Builder is to demonstrate to the Surveyor's satisfaction, that the number of plies can be laid wet on wet and that the resultant temperature during the cure cycle does not have any deleterious effect on the mechanical properties of the cured laminate.

3.3.10 Laminating is to be carried out in a sequence such that the time lapse between the application of the successive layers is within the limits recommended by the resin manufacturer and documented in the quality control procedures for the particular resin system. Similarly, the time lapse between the forming and bonding of structural members is to be kept within these limits and, where this is not practicable, the surface of the laminate is to be prepared, in accordance with the resin manufacturer's instructions, to improve the bond.

3.3.11 When laminating is interrupted, and where other than an epoxy resin system is being used, the first of any subsequent layers of reinforcement to be laid in that area is to be of chopped glass fibre or other type of material to enhance the interlaminar strength properties of the laminate.

3.4 Fibre content

3.4.1 To ensure that the resultant thicknesses of the structure is not less than that required to comply with those indicated on the approved plans, the nominal fibre content, by weight, of the individual plies and overall laminate is to be controlled on the basis of the weight of the constituent materials.

3.4.2 Continuous monitoring of resin/reinforcement usage is required for ongoing fibre content verification and is to be recorded under the quality control system, *see* Ch 14,5 of the Rules for Materials.

3.4.3 A method of validating the completed laminate thickness is to be agreed between the Builder and Surveyor. Where electronic thickness measurement methods are employed, the equipment is to be calibrated against a laminate of identical construction. Alternatively a series of areas are to be identified within the craft where samples can be taken to validate the thickness of the laminate (e.g. in way of overboard discharges/seawater intakes/deck openings, etc.).

3.5 Laminate schedule

3.5.1 The laminate schedule is to clearly define the logical sequence of production and is to identify the specific materials to be used.

3.5.2 The schedule is to define the extent of each reinforcement and state relevant details regarding overlapping, staggering thicknesses and tailoring of reinforcements.

3.5.3 Progressive thickness measurements in accordance with 3.4.3 are to be recorded as part of the quality control documentation and, where required, additional reinforcements are to be laid to attain the required thickness.

3.5.4 Areas of local deficiency requiring additional reinforcement and areas that have been found to be increased thickness are to be recorded in the quality control documentation.

3.6 Spray laminating

3.6.1 The equipment for spray deposition of resin and glass fibres is to be inspected during the Workshop Inspection and a sample panel produced. Documentary evidence of maintenance, calibration, catalyst content, fibre length and overall fibre content by weight are to be entered into the quality control documentation. The spray pattern is to give an even distribution, as recommended by the manufacturer of the equipment and is to be to the satisfaction of the attending Surveyor.

3.6.2 Special consideration is to be given to the production environment, ventilation equipment and quality control arrangements to ensure that the finished product meets the requirements of the approved plans.

3.6.3 Unless the mechanical properties are confirmed by testing, the chopped fibre length for a structural laminate is to be not less than 35 mm. In no case is the fibre length to be less than 25 mm.

3.6.4 Spray equipment is only to be operated by trained and competent personnel. Training certification is to form part of the quality control documentation. The use of spray lay-up is to be limited to the parts of the structure to which sufficient access can be obtained to ensure satisfactory laminating.

3.6.5 The weights of resin and reinforcement used is to be monitored continuously to check the glass/resin ratio. Samples are also be taken on a regular basis to validate the calibration of the equipment.

3.6.6 Where spray lay-up is used to back up the gel coat the weight of sprayed fibre is not to exceed 300 g/m^2, applied at a high resin content to give a glass content by weight, of not greater than 0,286. This should be consolidated by gentle rolling. This first layer of reinforcement is to be allowed to cure to a trimming state before proceeding with the remainder of the laminate.

3.6.7 Consolidation is to be carried out as soon as is practicable after spray deposition. In general, this is to be carried out when a weight of reinforcement equivalent to a thickness of 2–3 mm has been deposited. The thickness of the resulting laminate is to be periodically checked and recorded.

3.6.8 Particular attention is to be given to localised thinning of the laminate in way of chines, coamings, knuckles and openings. Further deposition may be required in such areas to compensate for any reduction in thickness. Alternatively, layers of other equivalent reinforcements may be laid to achieve the required local thickness.

3.7 Release and curing

3.7.1 After completion of the lay-up, the moulding is to be left in the mould for a period to allow the resin to cure before being removed. This period can vary with ambient temperature, the type of resin and the complexity of the moulding, but is to be not less than 12 hours or that recommended by the resin manufacturer.

3.7.2 Care is to be exercised during removal from the mould to ensure that the hull, deck and other large assemblies are adequately braced and supported to avoid damage to and maintain the form of the moulding.

3.7.3 Where female moulds are adopted, all primary stiffening and transverse bulkheads are to be installed prior to removal from the mould unless agreed otherwise on the approved construction schedule and plans.

3.7.4 Mouldings are not to be stored outside of the workshop environment until they have attained the stage of cure recommended by the resin manufacturer for that particular resin. Provision is to be made for mouldings to be protected against adverse weather conditions.

3.7.5 Mouldings are, in general, to be stabilised in the moulding environment for at least 24 hours, or that recommended by the resin manufacturer before the application of any special cure treatment, details of which are to be submitted for approval.

3.8 Barcol hardness

3.8.1 The degree of cure of mouldings is to be measured using a Barcol impressor model GYZJ 934-1 in accordance with BS 2782: Part 10: Method 1001: 1977 (1989) or other equivalent National or International Standard. Alternative equivalent standards of hardness measurement will be considered.

3.8.2 The hardness meter is to be regularly checked for calibration during use. A calibration certificate is to form part of the quality control documentation.

3.8.3 Removal from the mould is not to be attempted until a minimum Barcol reading recommended by the resin manufacturer or a value of 20 has been attained. Subsequently, the moulding is not to be moved outside of the controlled environment until a minimum Barcol reading recommended by the resin manufacturer of 35 (or equivalent) has been recorded.

3.9 Laminate detail

3.9.1 Changes in laminate thickness are to be made using a gradual taper. The length of such taper is, in general, not to be less than 20 times the difference in thickness. Where the construction changes from sandwich laminate to a solid laminate, the thickness of the core material is, in general, to be reduced by a gradual taper of not less than 2:1.

3.9.2 Framing and stiffening sections are to be built up layer by layer in accordance with an approved procedure, particular attention being given to ensure a satisfactory bond and structural continuity at the ends and intersections.

3.9.3 Discontinuities and hard points in the structure are to be avoided, and where the strength of a stiffening member is impaired by any attachment of fittings, openings, drainage arrangements, etc., compensation is to be provided.

3.9.4 Where items are prefabricated outside the mould, they are to be connected by boundary angles formed by layers of reinforcement, structural fillets or other approved method. Where structural fillets are proposed, the scantlings and arrangements will be specially considered.

3.9.5 Polyester, vinylester or epoxide resin may be used in bonded joints, provided that the joint is so designed that the resin bond is in shear. The contact area is to be as large as practicable and the surfaces are to be suitably prepared in accordance with the resin manufacturer's instructions.

3.9.6 The submitted plans are to clearly define the laminate sequence at corner joints. In general, corner laminates are to be boxed and all cuts are to be alternately staggered to avoid a fault line. At corner joints vertical and horizontal laminates are to be laid alternately and butts are to be staggered accordingly.

3.9.7 The submitted plans are to clearly define the details of scarfed joints. In general, scarfs are not to not be steeper than a 12:1 taper. Scarf joints may be either ground or stepped and may be single or double taper. Where single taper scarf joints are proposed, a sealing laminate is to be provided, details of which are to be submitted. Where stepped joints are proposed care is to be taken to ensure that over-cutting does not occur. All joints are to be arranged so that they can be reinforced internally to maintain structural continuity of the laminate.

3.9.8 Lap joints may be bolted or adhesively bonded, or both. They may be single or double lapped dependent upon the specific application.

3.9.9 Where tray mouldings form part of the integral structure of the craft, full details are to be indicated on the submitted plans. Information regarding tolerances is to be presented together with details of all adhesives and proposed bonding-in techniques. Particular attention is to be given to the design so as to maintain the structural continuity of the webs of any stiffening members.

3.9.10 The hulls of all craft with a service speed of 25 knots or greater are to be moulded as required by Ch 3,3.15.

3.9.11 Chine details are to be clearly indicated on the submitted plans. Spray rails may form part of the structural laminate or may be installed as a laminated or bolted appendage. Where the chine is a laminated appendage, provision is to be made for a sacrificial ply at which failure may occur without undue damage to the remaining structure of the hull. Sandwich structures are to be returned to single skin laminates at chine rails unless agreed otherwise on the approved construction plans. Chine rails are to be infilled and over laminated on the inner surface of the hull. Additional reinforcement is to be laminated into the chine area in accordance with Ch 3,3.8.

3.9.12 Reinforcements are to be arranged to maintain continuity of strength throughout the laminate. Joints in each layer of reinforcement are, in general, to be overlapped. The length of the overlap is dependent upon the type of reinforcement but is not to be less than 50 mm. The position of the joints in the laminate is to be staggered, in general by 150 mm, to maintain as near uniform laminate thickness as practicable. Tests may be required to demonstrate continuity of strength when bi-directional, multi-axial or cross plied reinforcements are used.

3.9.13 As an alternative to overlapping as required by 3.9.12, individual consideration will be given, on the basis of test results, to partial butting of reinforcements manufactured with a salvedge. For such reinforcements the salvedge tails are to be laid on top of each other to provide continuity. Butts in the same vertical plane are to be separated by not less than five passing plies.

3.9.14 Areas of single skin structure in way of the attachment of fittings or equipment are, in general, to be increased in thickness by not less than 50 per cent, with the additional layers staggered beyond the extremities of the surrounding stiffening.

3.9.15 The design of the structure in way of the attachment of fittings or equipment in sandwich structures is to be such that the induced loads can be transmitted into the surrounding structure by bending as opposed to shear. The areas are to, in general, take the form of suitably reinforced single skin areas, *see* 3.9.14, with the additional layers of reinforcement staggered out onto the surrounding inner and outer skins as indicated in Fig. 3.3.1.

3.9.16 Laminate overlapping and staggering arrangements may require to be tested at the discretion of the Surveyor.

3.9.17 Laminates may be fastened mechanically provided that the fastenings are of a corrosion resistant metal and are spaced and positioned so as not to impair the efficiency of the joint. The fastenings are to be of an acceptable type and, where washer plates are used, they are to be of a compatible material. The edges of the laminates and the fastening holes are to be sealed.

3.9.18 Where plywood and timber members are to be matted onto, or encapsulated within, the laminate, the surface of the wood is to be suitably prepared prior to bonding.

3.9.19 For details of through hull fittings, *see* 5.6.

■ *Section 4* Additional procedures for sandwich construction

4.1 General

4.1.1 The methods used in sandwich construction are, in general, to be either wet or dry core bonding techniques or by laminating directly onto the core (e.g. plug moulding).

4.2 Laminating

4.2.1 The forefoot and stem of all craft of composite construction are to be moulded as required by Ch 3,5.11.1.

4.2.2 Where the core material is to be laid onto a pre-moulded skin, it is to be laid as soon as practicable after the laminate cure has passed the exothermic stage.

4.2.3 Where the core is applied to a laminated surface, particular care is to be taken to ensure that a uniform bond is obtained. Where a core is to be applied to an uneven surface, the Surveyor may request additional building up of the surface or contouring of the core to suit.

4.2.4 Where other than epoxy resins are being used, the reinforcement against either side of the core is to be of the chopped strand mat type. Additional flow coating is not to be applied to the foam core prior to laminating.

4.2.5 The submitted plans are to clearly show the staggering of successive plies in both the transverse and longitudinal directions. In general laminates are to be staggered by 50 mm per layer of reinforcement. Where very thin sandwich skins are adopted the rate of laminate stagger will be individually considered.

4.2.6 Prior to bonding, the core is to be cleaned and primed (sealed) in accordance with the manufacturer's recommendations. The primer is to be allowed to cure and is not to inhibit the subsequent cure of the materials contained within the manufacturer's recommended bonding process. The primer is to seal the panels, including all the surfaces between the blocks of contoured material, without completely filling the surface cells.

4.2.7 Where panels of rigid core material are to be used then dry vacuum bagging techniques are, in general, to be adopted. The core is to be prepared by providing 'breather' holes to ensure efficient removal of air under the core. Bonding paste is to be visible at such breather holes after vacuum bagging. The number and pitch of such 'breather' holes is to be in accordance with the core manufacturer's application procedure and any specific requirements of the core bonding paste manufacturer, *see also* 4.4.3

4.2.8 Thermoforming of core materials is to be carried out in accordance with the manufacturer's recommendations. Maximum temperature limits are to be strictly observed.

4.2.9 Where panels of contourable core material are to be used it is necessary to ensure that the core is cut/scored through the entire thickness such that the panels will conform to the desired shape of the moulding. The Builder is to demonstrate that the quantity of bonding material indicated in the core manufacturer's application procedure (*see* 2.11.2) is sufficient to penetrate the full depth of the core between the blocks. It is recommended that grid scored panels using a carrier scrim cloth are adopted.

4.2.10 Where the edges of a panel are to be bevelled to single skin the rate of tapering is to be not greater than 30°. In areas where an insert (e.g. higher density foam or plywood) is to be used the rate of taper is not to be greater than 45°.

4.2.11 In all application procedures cured, excess bonding material is to be removed and the panel cleaned and primed prior to the lamination of the final sandwich skin.

4.3 Inserts

4.3.1 Backing or insert pads where fitted in way of the attachment of fittings are to be arranged so that the load can be satisfactorily transmitted into the surrounding structure. The contact area of these pads is to be suitably prepared and free from contamination, *see also* 3.9.14 and 3.9.15.

4.3.2 Inserts in sandwich laminates are to be of a material capable of resisting crushing. Inserts are to be well bonded to the core material and to the laminate skins in strict accordance with the approved plans.

4.3.3 Where plywood inserts are to be used all edges are to be bevelled at an angle of 45°. A small gap is to be provided around each insert to ensure the passage of bonding paste during the vacuum bagging process.

4.4 Vacuum bagging

4.4.1 Where wet vacuum bagging is proposed (with or without a core), full details are to be submitted for consideration.

4.4.2 The Builder is to demonstrate by visual inspection that efficient core bonding can be obtained using the proposed dry vacuum bagging process.

4.4.3 The number, size and distribution of breather holes in panels of rigid core material is to be that recommended in the core manufacturer's application procedure, *see* 4.2.6. Typically, 3 mm diameter breather holes are to be provided at 50 mm centres.

4.4.4 The level of vacuum applied for initial consolidation and during the cure period is not to be higher than that recommended, by the relevant manufacturer of the materials being used, to avoid the possibility of evaporative boiling and excessive loss of monomer.

4.5 Shear ties

4.5.1 Shear ties between the inner and outer skins are to be provided at intervals not greater than that required by Ch 3,1.13, and are to be detailed on the plans submitted for approval.

4.5.2 Alternative shear tie arrangements will be individually considered.

■ *Section 5* Details and fastenings

5.1 General

5.1.1 This Section contains the general Rule requirements to be complied with for fibre reinforced plastic craft being built under survey. Where detailed requirements are not defined good boat building practices are to be applied. Where different details are to be applied, the Builder is required to provide evidence of satisfactory service experience or acceptable test data.

5.2 Alignment

5.2.1 Details of alignment and building tolerances are to be laid down in the Builder's production plan.

5.2.2 Where details of alignment and building tolerances are not included on the construction plans, or submitted separately for consideration with the plan submission, they may, subject to individual consideration, be agreed locally with the attending Surveyor.

5.2.3 Particular attention is to be given to the accurate alignment of the following:
(a) girder abutting single skin bulkhead;
(b) girder webs with tank sides;
(c) frames with beams;
(d) deck/bottom girders with bulkhead stiffeners;
(e) tank baffles with floors;
(f) longitudinals where broken at tank ends; and
(g) transom stiffeners with bottom/deck girders.

5.2.4 For larger craft the hull breakage sight-line is to be progressively monitored during the construction of the craft and is to form part of the quality control documentation. The production plan is to identify maximum breakage limits dependent upon the size of the craft.

5.2.5 The production plan is to identify allowable tolerances for the alignment of the primary structural components.

5.2.6 To ensure efficient load transmission intercostal, single skin bulkheads are to be aligned to within half the thickness of the thinner bulkhead. In the case of sandwich construction the tolerance requirements will be individually considered dependent upon the sandwich panel dimensions and the construction of the continuous member. In general, the webs of the intercostal sandwich panel member are to be aligned to within 5 mm. Where poor alignment is identified, additional boundary bonding reinforcements are to be applied as agreed with the attending Surveyor. Such deviations and details of the remedial action taken are to be recorded in the Builder's quality control documentation.

5.2.7 To ensure efficient transmission of shear loads, the alignment tolerance of intercostal 'top hat' stiffener webs is, in general, to be within half of the web thickness. Where poor alignment is identified, additional reinforcements are, in general, to be incorporated into the stiffener webs as agreed with the attending Surveyor. Such deviations and details of the remedial action taken are to be recorded in the Builder's quality control documentation.

5.3 Continuity

5.3.1 Continuity of all primary structural members is to be maintained, as required by the Rules, and abrupt changes of section are to be avoided. Both primary and secondary stiffening members are to be continuous unless otherwise agreed with LR.

5.3.2 Special consideration will be given to the intersection of longitudinal and transverse members. In general the ratio between the depths of the intersecting members is to be 2:1. The shallower member is to be continuous under the supporting members.

5.3.3 Alternative proposals to the requirements given in 5.3.2 will be subject to special consideration in conjunction with the submission of details for maintaining the continuity of reinforcements at intersections in both directions. Where stiffeners are of similar dimensions the primary member is to be continuous. In general the section modulus of the continuous material is to be maintained.

5.4 Openings

5.4.1 All openings are to have well rounded corners and are to be supported on all sides. Cut edges of openings are to be sealed to prevent the ingress of moisture.

5.4.2 All hatch openings are to be supported by a system of transverse and longitudinal stiffeners, the details of which are to be submitted for approval.

5.4.3 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

5.4.4 All deck openings are to have corner radii as specified in Ch 3,8.12.

5.4.5 For details of sealing the edges of openings and sandwich panels, *see* 5.10.

5.5 Through bolting and bolted connections

5.5.1 The details of all through bolted structural connections are to be indicated on the relevant construction plans submitted for approval. The design of the joint is to be suitable for its intended purpose with a sufficient number of bolts to satisfactorily close the joint.

5.5.2 Tank tops may be bolted down provided the bolt spacing does not exceed $8d_b$, where d_b is the bolt diameter. A joint, seal or stop water is to be fitted, as necessary, to meet the required integrity.

5.5.3 In general, large headed bolts or large diameter thick washers are to be used to prevent localised crushing damage during tightening.

5.5.4 Where mechanical fastenings are used, the torque is to be indicated on the plans submitted for approval.

5.5.5 Bolting arrangements are, in general, to be in accordance with Ch 2,5.5, 5.6, 5.7 and 5.8. In FRP sandwich construction, inserts of a material capable of resisting crushing are to be fitted in accordance with 4.3.

5.5.6 The diameter of a fastening is not to be less than the thickness of the thinner component being fastened, with a minimum diameter of 6 mm, excepting window frames where the minimum diameter may be 5 mm.

5.5.7 Bolted connections are, in general, to be bonded along all mating surfaces using an accepted structural adhesive, applied in accordance with the manufacturer's requirements. Where connections rely solely on the shear resistance of the connecting bolts the spacing is not to exceed $3d_b$, where d_b is the diameter of the bolt. In areas where subsequent access will either be limited or not possible, self locking nuts are to be provided.

5.5.8 In general, all structural, bolted connections are to use reeled lines of bolts in accordance with the requirements given in Table 2.5.1.

Table 2.5.1 Bolt pitch requirements in bonded and bolted connections

Location	Pitch
Watertight connections – below static load waterline	 $10d_b$
Connections in hull above static load waterline to deck	$15d_b$
Hull to deck connections – bonded with structural adhesive – bolted with mastic sealant (*see* Note 2)	 $20d_b$ $20d_b$
Connections in deckhouses	$20d_b$
Deckhouse to deck connections – bonded with structural adhesive – bolted with mastic sealant (*see* Note 2)	 $20d_b$ $20d_b$
Minimum distance between reeled lines of bolts	$3d_b$
Minimum distance from centreline of line of bolts to free edge	$2d_b$
NOTES 1. d_b is the diameter of the bolt. 2. Internal boundary sealing angle to be provided.	

5.5.9 All structural, single line, bolted connections without adhesive bondings are to be in accordance with the requirements given in Table 4.1.1 in Pt 3, Ch 4.

5.5.10 Care is to be taken to avoid distortion of the frame when window frames are bolted into the structure of the craft. Where necessary, uneven surfaces are to be locally built up to the satisfaction of the attending Surveyor.

5.5.11 Where a restricted service notation of G1 or G2 is applicable the requirements given in this Section will be specially considered dependent upon the sea states for which the craft is designed.

5.5.12 Bolt holes are to be drilled, without undue pressure at break through, having a diametric tolerance of two per cent of the bolt diameter. Where bolted connections are to be made watertight the hole is to be sealed with resin and allowed to cure before the bolt is inserted.

5.5.13 In areas of high stress or where unusual bolting configurations are proposed, testing on the basis of equivalence with the above Rules may be required.

5.6 Through hull fittings

5.6.1 Where fittings penetrate the hull envelope, care is to be taken to seal the hull laminate with resin or other suitable compound, *see* 5.10.

5.6.2 The areas in way of penetrations for fittings in sandwich construction are, in general, to comply with the requirements of 4.3. Where the requirements cannot be complied with, the core is to be replaced locally with a solid core or very high density foam core with compressive properties commensurate with the loads imposed by the securing arrangements, *see* 5.8.2. The exposed edges of such openings are to be sealed watertight, *see* Ch 3,3.10.

5.6.3 All bolted fittings are to be bedded down using a suitable mastic, details of which are to be indicated on the submitted plans.

5.7 Backing bars and tapping plates

5.7.1 The requirements for backing plates and bars will be individually considered, on the basis of the loading imposed, details of which are to be indicated on the submitted plans.

5.7.2 Metallic plates and bars are to be suitably protected against corrosion.

5.7.3 Tapping plates may be encapsulated within the laminate, laminated to or bolted to the structure, *see also* 2.15.1. Where tapping plate edges or corners are likely to give rise to hard spots or stress concentrations the edges are to be suitably rounded.

5.7.4 Where tapping plates are placed on foam cores the plate is to be mounted on a suitable foundation to prevent the movement of the tapping plate during drilling operations.

5.7.5 Direct calculations regarding the scantlings of tapping plates are to be provided at the plan appraisal stage.

5.8 Fastenings

5.8.1 All fastenings are to be of a suitable marine grade. Sizes and specifications are to be indicated on the submitted plans.

5.8.2 In areas where localised crushing of a sandwich core is likely to occur, large diameter washers, compression tubes or inserts or a combination of these are to be adopted.

5.9 Secondary bonding

5.9.1 Laminating is to proceed as a continuous process, as far as practicable, with the minimum of delay between successive plies. Where a secondary bond is to be made it is to be carried out in accordance with the resin manufacturer's recommendation, details of which are to be incorporated in the Builder's quality control documentation. This will, in general, take the form of the area being lightly abraded and wiped with a suitable solvent, which is to be allowed to dry prior to laminating.

5.9.2 Where other than epoxy resins are being used, the first reinforcement is to be of the chopped strand mat type.

5.9.3 Consideration should be given, especially in highly stressed areas, to the application of peel ply materials to obviate contamination of the exposed surface, and thereby reducing the abrading required to obtain a good secondary bond.

5.10 Exposed edges

5.10.1 The exposed edges of all openings cut in single skin laminate panels are to be suitably sealed. Where such edges are in wet spaces or under water the edges of such openings are to have rounded edges and are to be sealed by two plies of 450 g/m^2 chopped strand mat (or equivalent) reinforcements, *see also* Ch 3,3.10.

5.10.2 Exposed edges of openings cut in sandwich panels are to be suitably sealed, *see* 5.6.2. The cut edges are, in general, to be sealed with a weight of reinforcement not less than that required for the outer skin of the sandwich. Where other than an epoxy resin system is used the first layer of such reinforcement is to be chopped strand mat with a weight not exceeding 450 g/m^2, *see also* Ch 3,3.10.

5.11 Joints

5.11.1 The details of all joints, the proposed jointing procedure and information regarding tolerancing are to be indicated on the submitted plans.

5.11.2 Joints may be bolted or adhesively bonded, or both. Where joints are bolted, full details of the bolt material, the proposed number and spacing are to be provided. Bolts are to be manufactured from a non-corrosive material or protected against corrosion.

5.12 Local reinforcement

5.12.1 Areas subject to local loads or increased stress are to be suitably reinforced, details of which are to be indicated on the submitted plans, *see also* Ch 3,3.14.

5.12.2 Areas of local reinforcement will be individually considered and direct calculations are to be submitted, *see* 3.9.14.

5.13 Hull to deck connections

5.13.1 Details of the hull to deck connection, the method of bonding and the tolerances are to be indicated on the submitted plans.

5.13.2 Hull to deck connections should, in general, be bolted and over-bonded. A suitable mastic or sealing compound is to be incorporated within the joint.

5.13.3 The bolting details should be reeled lines of bolts pitched as specified in Table 2.5.1. Suitable large diameter thick washers should be used under both the head and the nut.

5.13.4 Where a mastic is not used, sealing plies are to be applied on the inside of the hull.

5.13.5 The weight of the over-bonding reinforcement is, in general, not to be taken as less than equivalent to the lighter of the component members being connected, and in no case less than equivalent to three plies of 600 g/m^2 chopped strand mat.

5.13.6 Substantial beam knees are to be provided to maintain structural continuity between the transverse deck and hull stiffening.

5.13.7 The watertight integrity, continuity and strength of the connection is not to be impaired by the attachment of the hull fender.

5.13.8 For guidance details of scantlings required to resist impact loads at deck edge connections, *see* Ch 3,4.19 for side shell in way of fendering and Ch 3,3.6 for sheerstrakes.

5.14 Exhaust systems

5.14.1 Exhaust systems, manufactured from FRP, are to be of the water injected type with a normal operating temperature of 60° to 70°C and a maximum operating temperature of 120°C.

5.14.2 Exhaust pipes, silencers and water separators should be of a Type Approved design, installed strictly in accordance with the manufacturer's requirements.

5.14.3 Where a Type Approved system is not used, the arrangement will be considered on an individual basis. Resins used in the manufacture of exhaust systems are to be of a type approved by LR and are to have good heat and chemical resistance properties with a high deflection temperature under load. A vinylester resin should be used, but a fire retardant polyester resin, having a high heat distortion temperature, will be considered. Test samples may be required dependent upon the proposed arrangement, temperatures and materials.

5.14.4 It is recommended that pigments and additives are not used unless it can be demonstrated that the mechanical properties of the resin system remain unaffected. Resins used are not to show any embrittlement with age.

5.14.5 Special consideration is to be given to post curing of such systems to obtain optimal characteristics.

5.14.6 Due to the weight of water contained within the system, exhaust pipes and fittings are to be efficiently supported.

5.14.7 Exhaust boxes are to be lined with a minimum of two plies of 600 g/m^2 chopped strand mat (or equivalent) using a suitable fire retardant/high temperature resin.

5.14.8 For engineering aspects of exhaust systems reference is to be made to Pt 10, Ch 1,8.6.

5.14.9 National Authority requirements take precedence over the requirements given in this Section.

5.15 Ballast

5.15.1 The provision of permanent ballast is not to adversely affect the surrounding structure.

5.15.2 Where a resin compound is to be poured into a void space, care is to be taken to minimise the generation of heat that may affect the mechanical and weathering characteristics of the structural laminate.

5.15.3 Details of all ballast materials and the proposed method of installation are to be indicated on the submitted plans.

5.16 Limber holes

5.16.1 Provision is to be made to drain areas likely to accumulate liquids, details of which are to be indicated on the submitted plans.

5.16.2 The size, shape and position of limber holes are not to affect the structural strength of the stiffening members in which they are fitted. Limber holes are, in general, to be positioned at the quarter span of the stiffener.

5.17 Integral tanks (requirements for coatings)

5.17.1 The surfaces of integral tanks are to be provided with a barrier to reduce the ingress of liquid. The details of the proposed system are to be indicated on the submitted plans.

5.17.2 Fresh water tanks are to be coated with a non-toxic and non-tainting coat of resin that is recommended by the resin manufacturer for potable water tanks.

5.17.3 The design and arrangement of oil fuel tanks is to be such that there is no exposed horizontal section at the bottom that could be exposed to a fire. Other fire protection arrangements for oil fuel tanks will be specially considered. For details of fire protection requirements, *see* Part 17.

5.17.4 Where plywood bulkheads form part of a tank boundary, the surface is to be completely protected against the ingress of moisture with a minimum of 4 mm thickness of laminate to provide an effective fluid barrier, regardless of resin and reinforcement type used.

5.17.5 Where outfit items are to be laminated to the tank surface, the heavy coating of resin is to be applied afterwards and the laminated brackets sealed to prevent the ingress of moisture.

5.17.6 The scantlings of integral oil fuel and water tanks are to be in accordance with Ch 3,7. Details regarding sub-division of integral tanks are given in Ch 3,7.11.1.

5.17.7 Integral tanks are to be tested in accordance with Ch 3,7.17.

5.18 Reserve buoyancy

5.18.1 Details of materials to be used and the method of installation of reserve buoyancy are to be indicated on the submitted plans.

5.18.2 Where necessary, buoyancy materials are to be over-laminated *in situ* to prevent the ingress of moisture.

5.19 Shear ties (stiffeners)

5.19.1 Where the total web depth to thickness ratio requirement in Ch 3,1.16 for buckling of stiffener webs is not complied with, cross linking of the stiffener webs at the Rule depth to thickness ratio is to be provided by the use of shear ties, as indicated in Fig. 2.5.1.

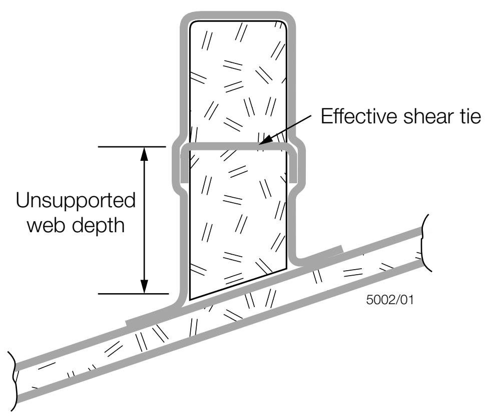


Fig. 2.5.1 Arrangement of shear ties (stiffeners)

5.19.2 Alternative arrangements will be subject to individual consideration in conjunction with submitted direct calculations.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull craft of composite construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 The scantlings of motor and sailing, mono-hull craft of conventional form and proportions are to be determined from the formulae contained within this Chapter.

1.2.2 The mechanical properties to be used for scantling calculation purposes are to be 90 per cent of the mean first ply/resin cracking failure values determined from accepted mechanical tests, or the mean values minus twice times the standard deviation for the five samples, whichever is the lesser. All test pieces are to be representative of the product to be manufactured and details submitted for consideration.

1.2.3 In the absence of suitable test data, the mechanical properties of the materials is to be estimated from the appropriate procedures and formulae contained within this Part. The acceptable design values for glass reinforced polyester resin laminates are, in general, not to be taken greater than those determined from Tables 3.1.1 and 3.1.2. Additional information on the application of the various formulae is given in Lloyd's Register's (hereinafter referred to as 'LR') *Guidance Notes for Calculation Procedures for Composite Construction*.

Table 3.1.1 Mechanical properties for chopped strand mat (CSM) reinforcements

Mechanical property	N/mm^2
Ultimate tensile strength	$200G_c + 25$
Tensile modulus	$(15G_c + 2) \times 10^3$
Ultimate compressive strength	$150G_c + 72$
Compressive modulus	$(40G_c – 6) \times 10^3$
Ultimate shear strength	$80G_c + 38$
Shear modulus	$(1,7G_c + 2,24) \times 10^3$
Ultimate flexural strength	$502G_c^2 + 106,8$
Flexural modulus	$(33,4G_c^2 + 2,2) \times 10^3$
NOTE G_c is as defined in 1.2.6.	

Table 3.1.2 Mechanical properties for woven roving (WR) and cross plied (CP) reinforcements at 0/90° degree orientation

Mechanical property	N/mm^2
Ultimate tensile strength	$400G_c – 10$
Tensile modulus	$(30G_c – 0,5) \times 10^3$
Ultimate compressive strength	$150G_c + 72$
Compressive modulus	$(40G_c – 6) \times 10^3$
Ultimate shear strength	$80G_c + 38$
Shear modulus	$(1,7G_c + 2,24) \times 10^3$
Ultimate flexural strength	$502G_c^2 + 106,8$
Flexural modulus	$(33,4G_c^2 + 2,2) \times 10^3$
NOTE G_c is as defined in 1.2.6.	

1.2.4 The various formulae referred to in 1.2.3 require that sufficient input data be available which relates to each of the proposed materials. The designers and/or Builders are to, in general, agree the values for use in the scantling analysis with LR at the design stage and prior to the submission of plans and data for appraisal.

1.2.5 Typical acceptable values for the various fibre properties of materials commonly in use are given in Table 3.1.3.

Table 3.1.3 Typical minimum fibre properties

	Specific gravity ζ_F	Tensile modulus N/mm^2	Shear modulus N/mm^2	Poisson's ratio μ_F
E glass	2,56	69000	28000	0,22
S glass	2,49	69000	— (*see* Note 3)	0,20
R glass	2,58	— (*see* Note 3)	— (*see* Note 3)	— (*see* Note 3)
Aramid	1,45	124000	2800	0,34
LM graphite (*see* Note 1)	1,80	230000	— (*see* Note 3)	— (*see* Note 3)
IM graphite (*see* Note 1)	1,80	270000	— (*see* Note 3)	— (*see* Note 3)
HM graphite (*see* Note 1)	1,8	300000	— (*see* Note 3)	— (*see* Note 3)
IM graphite (*see* Note 2)	1,9	160000	— (*see* Note 3)	— (*see* Note 3)
HM graphite (*see* Note 2)	2,0	380000	— (*see* Note 3)	— (*see* Note 3)
VHM graphite (*see* Note 2)	2,15	725000	— (*see* Note 3)	— (*see* Note 3)

NOTES
1. Polyacryonitrile type.
2. Mesophase pitch precursor type.
3. Actual values to be obtained from the material manufacturer and are to be agreed with LR prior to use.

1.2.6 **Uni-directional reinforcements**, the tensile properties of uni-directional laminates, consisting of E-glass and polyester resin, are to be determined from the procedures contained within this Part. Acceptable design values are, in general, not to be greater than those determined from the following:

Ultimate tensile strength (UDR)
$= 1800G_c^2 - 1400G_c + 510$ N/mm^2

Tensile modulus (UDR)
$= (130G_c^2 - 104G_c + 39) \times 10^3$ N/mm^2

where G_c is the glass content by weight of the reinforcement within the laminate.

1.2.7 Typical acceptable values for the various resin properties of materials commonly in use are given in Table 3.1.4.

1.3 Direct calculations

1.3.1 The scantlings are to be determined by direct calculation where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots.

1.3.2 The requirements of this Section may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 LR will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Ch 2,3 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter, unless specified otherwise, are defined as follows:

b = unsupported panel breadth, in mm
b_i = breadth of individual ply, *i*, in mm
e_f = flexural strain of plate laminate
B = moulded breadth of the craft, in metres
E_{ci} = compressive modulus of individual ply, *i*, in N/mm^2
E_{cp} = compressive modulus of plate laminate, in N/mm^2
E_i = E_{ti} or E_{ci} for the ply relative to its position above or below the neutral axis
E_F = tensile modulus of the fibres, in N/mm^2
E_R = tensile modulus of the resin, in N/mm^2
E_{ti} = tensile modulus of individual ply, *i*, in N/mm^2
E_{cps} = compressive modulus of the sandwich skin plate laminate as determined from 1.13.5, in N/mm^2
E_{tps} = tensile modulus of the sandwich skin plate laminate as determined from 1.13.4, in N/mm^2
E_{fp} = flexural modulus of plate laminate, in N/mm^2

Table 3.1.4 Typical minimum resin properties

	Type	Specific gravity ζ_R	Tensile modulus N/mm^2	Shear modulus N/mm^2	Poisson's ratio ν_R
Polyester	Thermosetting	1,20	3400	1300	0,36
Vinylester	Thermosetting	1,44	3500	— (*see* Note)	— (*see* Note)
Epoxy	Thermosetting	1,38	3500	— (*see* Note)	0,39
Phenolic	Thermosetting	1,30	1500~2500 (*see* Note)	— (*see* Note)	— (*see* Note)

NOTE
Actual value to be obtained from the material manufacturer and is to be agreed with LR prior to use.

E_{tp} = tensile modulus of the plate laminate, in N/mm^2
f_{ci} = fibre content, by weight, of individual ply, i
G = shear modulus of sandwich core material, in N/mm^2
I_i = second moment of area for a 1 cm length of the cross section of individual ply, i, in cm^4
I_P = second moment of area for a 1 cm length of the cross section of plate laminate, in cm^4
k_A = $85/\sigma_u$
k_s = sandwich laminate aspect ratio correction factor, as defined in 1.13.9
L_R = Rule length of craft, in metres
M = bending moment, as appropriate, in Nm
l_e = effective span length of stiffener, in metres
σ_u = ultimate tensile strength of the plate laminate, in N/mm^2
p = design pressure in kN/m^2, as calculated in Part 5 for the appropriate item
s = stiffener spacing, in mm
t_c = core thickness, in mm
t_i = thickness of individual ply, i, in mm
t_p = thickness of plate laminate, in mm
t_s = mean skin thickness, in mm
ν_F = Poisson's ratio for the fibre
ν_R = Poisson's ratio for the resin
V_{Fi} = volume fraction of fibres of individual ply, i
W_{Fi} = weight fraction of the fibres of individual ply, i
m_{Fi} = mass of reinforcement in individual ply, i, in g/m^2
x_i = distance to the centre of individual ply, i, from the plate or sandwich laminate surface, in mm
x_L = distance of the neutral axis from the surface of the plate or sandwich laminate, in mm
x_S = the distance of the neutral axis, from the outer surface of the plate or sandwich laminate
y_i = distance from the neutral axis to the outer extremity of an individual ply, i, in mm
σ_{ci} = maximum compressive stress within ply, i, in N/mm^2
σ_{ti} = maximum tensile stress within ply, i, in N/mm^2
ζ_{Fi} = specific gravity of reinforcement in individual ply, i
ζ_{Ri} = specific gravity of resin in individual ply, i.

1.5.2 The side shell is defined as the portion of the hull between the bottom shell and the deck at side.

1.6 Material properties

1.6.1 The nominal thickness of an individual ply, t_i, may be determined from:

$$t_i = \frac{m_{Fi}\left[\dfrac{\zeta_{Fi}}{f_{ci}} - (\zeta_{Fi} - \zeta_{Ri})\right]}{1000\zeta_{Fi}\,\zeta_{Ri}} \text{ mm}$$

where

f_{ci}, t_i, m_{Fi}, ζ_{Fi} and ζ_{Ri} are as defined in 1.5.1.

1.7 Effective width of attached plating

1.7.1 The geometric properties of stiffening sections are to be calculated in accordance with 1.15 using an effective width, $2b_1$, of attached load bearing plating determined as follows:

(a) Single skin construction:
$b_1 = 0{,}5b_w + 10t_{ap}$
(b) Sandwich skin construction:
Generally:
$b_1 = 0{,}5b_w + 10(t_{outer} + t_{inner})$
Where a plywood core is used:
$b_1 = 0{,}5b_w + 10(t_{outer} + t_{inner} + 0{,}5t_{ply})$
where
b_1 = effective width of attached load bearing plating, in mm, and is not to be taken as greater than one half the spacing between the centres of adjacent stiffeners
b_w = base width of the stiffener section, in mm
t_{ap} = thickness, or mean thickness of attached plate laminate, in mm
t_{inner} = thickness, or mean thickness of inner skin laminate, in mm
t_{outer} = thickness, or mean thickness of outer skin laminate, in mm
t_{ply} = thickness of plywood core, in mm.

1.7.2 The geometric properties of primary support members (i.e. girders, stringers, web frames, etc.) are to be calculated in accordance with 1.15 using an effective area of attached load bearing plate laminate of nominal thickness, t mm, and of width equal to one-half the sum of spacings between parallel adjacent members or equivalent support.

1.8 Glass fibre and advanced fibre composites

1.8.1 Strength calculations for all advanced fibre composites are to be based on the results of testing of truly representative sections of the proposed design. In general the sections are to be manufactured under typical production conditions using the same materials, fibre contents, methods of lay-up and time delays.

1.8.2 Mechanical testing is, in general, to be based upon the requirements of Ch 14,3 of the Rules for Materials.

1.8.3 Where test data is not available for standard glass fibre laminates, the following theoretical approach is to be used to estimate the tensile modulus and the shear modulus of a laminate:
The tensile modulus of a uni-directional reinforcement at angle θ to the axis of the fibres is to be determined from:

$$E_{\theta i} = \frac{E_{0i}}{\cos^4\theta_i + \dfrac{E_{0i}}{E_{90i}}\sin^4\theta_i + \dfrac{1}{4}\left(\dfrac{E_{0i}}{G_{0/90i}} - 2\nu_{0/90i}\right)\sin^2 2\theta_i} \text{ N/mm}^2$$

where
θ_i = angle of orientation of the fibre relative to the warp direction, and is not to be taken as less than seven degrees to allow for misalignment

E_{0i}, the longitudinal tensile modulus of individual ply, i, for an unfilled resin system is determined from:

$$E_{0i} = E_F V_F + E_R (1 - V_F) \ \text{N/mm}^2$$

E_F, V_F and E_R are as defined in 1.5.1

V_F, the volume fraction of the fibres of individual ply, i, is determined from:

$$V_F = \frac{W_F \zeta_R}{W_F \zeta_R - W_F \zeta_F + \zeta_F}$$

W_F, ζ_F and ζ_R are as indicated in 1.5.1

E_{90i}, the transverse tensile modulus of individual ply, i, is determined from:

$$E_{90i} = \frac{E_F E_R}{E_R V_F + E_F - E_F V_F} \ \text{N/mm}^2$$

E_F, E_R and V_F are as indicated in 1.5.1.

$G_{0/90i}$, the shear modulus of individual ply, i,is determined from:

$$G_{0/90i} = G_R \left\{ \frac{\frac{G_F}{G_R}(1 + V_F) + (1 - V_F)}{\frac{G_F}{G_R}(1 - V_F) + (1 + V_F)} \right\} \ \text{N/mm}^2$$

Where the shear modulus of the resin, G_R is determined from:

$$G_R = \frac{E_R}{2(1 + \nu_R)} \ \text{N/mm}^2$$

Where the shear modulus of the fibre, G_F is determined from:

$$G_F = \frac{E_F}{2(1 + \nu_F)} \ \text{N/mm}^2$$

E_F, E_R, ν_R and ν_F are as indicated in 1.5.1.

The longitudinal Poisson's ratio, $\nu_{0/90}$, of individual ply, i, is determined as follows:

$$\nu_{0/90} = V_F (\nu_F - \nu_R) + \nu_R$$

V_F, ν_F and ν_R are as indicated in 1.5.1.

1.8.4 Where specific test data is not available for glass fibre reinforced polyester laminates, the mechanical properties for design are to be the values determined from the formulae given in Tables 3.1.1 and 3.1.2.

1.9 Plate and sandwich laminates

1.9.1 Unless otherwise specified in this Part, the bending moments, M_b and M_c, to be applied to a 1 cm length of panel, for both plate and sandwich laminates, subjected to lateral pressure are to be determined from:

(a) Bending moment at panel boundary and under base of stiffener, M_b:

$$M_b = \frac{k\,p\,b^2}{12} \times 10^{-5} \ \text{Nm}$$

(b) Bending moment at centre of panel, M_c:

$$M_c = \frac{(1{,}5 - k)\,p\,b^2}{12} \times 10^{-5} \ \text{Nm}$$

where

$$k = \frac{\gamma^3 + 1}{\gamma + 1}$$

$$\gamma = \frac{b_w}{b}$$

b_w < b and is as defined below, *see* Fig. 3.1.1:
b = unsupported panel breadth, in mm
b_w = base width of stiffener, in mm
γ = ratio of base width of stiffener to panel breadth
k = bending moment influence coefficient
l_p = panel length, in mm
p = design pressure head as required by Part 5, for the element of plate laminate under consideration, in kN/m^2.

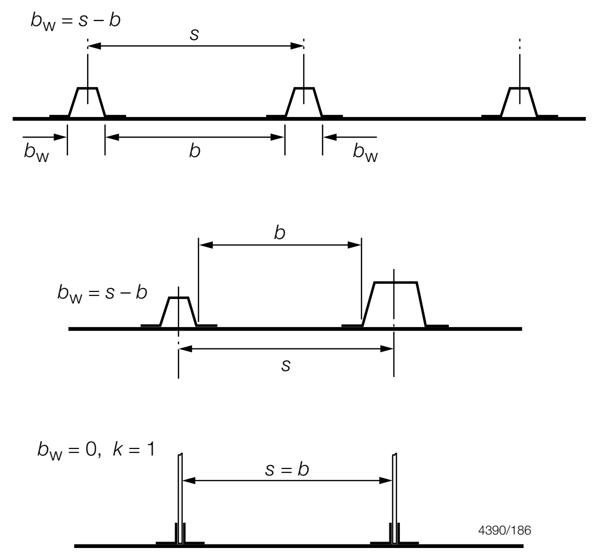


Fig. 3.1.1 Panel dimensions

1.10 Aspect ratio correction

1.10.1 The Rule bending moments, M_b and M_c, to be applied to plate laminates as determined by 1.9.1, may be reduced when the panel aspect ratio is taken into consideration. For panels with aspect ratio less than two the following factor, K_{AR}, may be applied:

$$K_{AR} = 0{,}56 + 0{,}63 \ln(A_R) \geq 0{,}56$$

where
A_R = panel aspect ratio
= panel length/panel breadth

1.11 Convex curvature

1.11.1 The Rule bending moments, M_b and M_c, as determined by 1.9.1, may be reduced where significant curvature exists between the support members. For such panels the following factor, K_c, may be applied:

$$K_c = 1 - 1{,}76 \frac{h}{s} \geq 0{,}56$$

where

h = the distance, in mm, measured perpendicularly from the chord length s (i.e. spacing) to the highest point of the curved plating arc between the two supports, *see* Fig. 3.1.2.

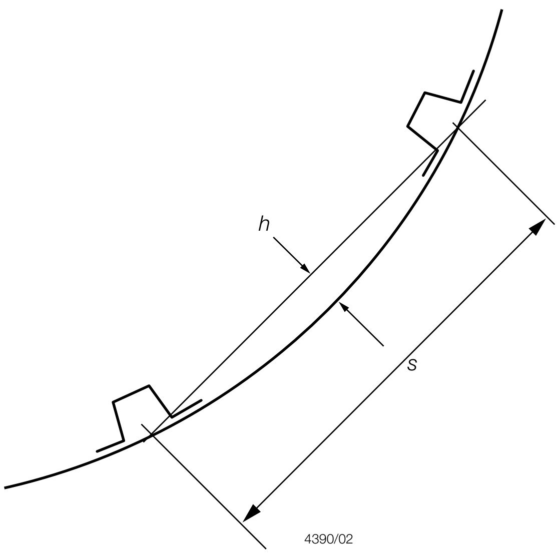


Fig. 3.1.2 Convex curvature

1.12 Determination of properties and stresses for single skin plate laminates

1.12.1 An estimate of the thickness of single skin plating required to carry the bending moment given in 1.9.1, is to be determined from:

$$t = 0{,}146b \sqrt[3]{\frac{p}{E_{tp}}} \text{ mm}$$

where

b, p and E_{tp} are as defined in 1.5.1.

1.12.2 The distance of the neutral axis, x_L, from the surface of the plate laminate is to be determined from the following:

$$x_L = \frac{\Sigma (E_i\, t_i\, x_i)}{\Sigma (E_i\, t_i)} \text{ mm}$$

where

E_i, t_i and x_i are as defined in 1.5.1.

1.12.3 The resultant tensile stress, σ_{ti}, at the extreme outer fibre of an individual ply, i, is to be determined from:

$$\sigma_{ti} = \frac{0{,}1 E_{ti}\, y_i\, M}{\Sigma (E_i\, I_i)} \text{ N/mm}^2$$

where

σ_{ti}, E_{ti}, y_i, M, E_i and I_i are as defined in 1.5.1.

1.12.4 The resultant compressive stress, σ_{ci}, at the extreme outer fibre of an individual ply, i, is to be determined from:

$$\sigma_{ci} = \frac{0{,}1 E_{ci}\, y_i\, M}{\Sigma (E_i\, I_i)} \text{ N/mm}^2$$

where

σ_{ci}, E_{ci}, y_i, M, E_i and I_i are as defined in 1.5.1.

1.12.5 The effective flexural modulus of elasticity in bending, E_{fp}, for the plate laminate is to be determined from:

$$E_{fp} = \frac{\Sigma (E_i\, I_i)}{I_p} \text{ N/mm}^2$$

where

E_{ti}, I_i and I_P are as defined in 1.5.1.

1.12.6 The apparent flexural strength, sf, of a plate laminate is to be determined from:

$$\sigma_f = E_{fp}\, e_f \text{ N/mm}^2$$

where

E_{fp} and e_f are as defined in 1.5.1.

1.13 Mechanical properties sandwich laminates

1.13.1 For the application of the various formulae relating to the use of sandwich construction, the following assumptions have been made:

(a) the sandwich skins carry all of the bending load,
(b) the core carries all of the shear load,
(c) the initial estimate of the skin thickness from 1.13.2 is based upon the limiting condition for thin skin theory:

$$\frac{\text{Core thickness}}{\text{Mean facing thickness}} \geq 5{,}77$$

(d) the sandwich skins are of approximately equal thickness (i.e. the panel is of balanced or approximately balanced construction), with the thickness of the outer sandwich facing not greater than:

t_{OUTER} = 1,33 t_{INNER} (excluding gel coat and non-structural materials).

1.13.2 An estimate of the thicknesses of the sandwich skins and core required to carry the Rule bending moment may be determined from the following formula. The subsequent design is then to be tested against the other criteria required by the Rules.

$$t_s = \phi_1\, k_S\, b \sqrt[3]{\frac{p}{E_{tps}}} \text{ mm}$$

where

ϕ_1 = 0,0214 for inner skins
= 0,0286 for outer skins
= 0,1440 for core thickness

k_S, E_{tps}, b and p are as defined in 1.5.1.

1.13.3 Where it is proposed to use a thicker core than assumed in 1.13.2, the required skin thickness, t_s, is to be calculated from:

$$t_s = \frac{\phi^2\, p\, b^3}{E_{tps}\, t_c^2} \times 10^{-3} \text{ mm}$$

where

ϕ_2 = 0,446 for inner skins
= 0,594 for outer skins

k_S, E_{tps}, b and p are as defined in 1.5.1.

1.13.4 The tensile modulus, E_{tp}, of a plate laminate which forms a skin of a sandwich laminate subject to tensile loading is to be determined from:

$$E_{tps} = \frac{\Sigma\,(E_{ti}\,t_i)}{\Sigma\,t_i} \text{ N/mm}^2$$

where

E_{tps}, E_{ti} and t_i are as defined in 1.5.1.

1.13.5 The compressive modulus, Ecp, of a plate laminate which forms a skin of a sandwich laminate subject to compressive loading is to be determined from:

$$E_{cps} = \frac{\Sigma\,(E_{ci}\,t_i)}{\Sigma\,t_i} \text{ N/mm}^2$$

where

E_{cps}, E_{ci} and t_i are as defined in 1.5.1.

1.13.6 The distance of the neutral axis, x_S, from the outer surface of the sandwich laminate is to be determined from:

$$x_S = \frac{\Sigma\,(E_i\,t_i\,x_i)}{\Sigma\,(E_{ti}\,t_i)} \text{ mm}$$

where

E_i, t_i and x_i are as defined in 1.5.1.

1.13.7 The resultant tensile stress, σ_{ti}, at the extreme outer fibre of an individual ply, *i*, is to be determined from:

$$\sigma_{ti} = \frac{0{,}1 E_{ti}\,y_i\,M}{\Sigma\,(E_i\,I_i)} \text{ N/mm}^2$$

where

σ_{ti}, E_{ti}, y_i, M, E_i and I_i are as defined in 1.5.1.

The allowable tensile stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

1.13.8 The resultant compressive stress, σ_{ci}, at the extreme outer fibre of an individual ply, *i*, is to be determined from:

$$\sigma_{ci} = \frac{0{,}1 E_{ci}\,y_i\,M}{\Sigma\,(E_i\,I_i)} \text{ N/mm}^2$$

where

σ_{ci}, E_{ci}, y_i, M, E_i and I_i are as defined in 1.5.1.

The allowable compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

1.13.9 The direct core shear stress, τ_c, at the edges of a sandwich panel subjected to lateral pressure is to be determined from:

$$\tau_c = \frac{p\,b\,k_S}{2t_c} \times 10^{-3} \text{ N/mm}^2$$

where

k_S = aspect ratio correction factor
= $0{,}32\,A_R + 0{,}36$ for $A_R \le 2$
= 1,0 for $A_R > 2$

A_R = panel length/panel breadth

t_c is as defined in 1.5.1.

The allowable shear stress limits against core shear failure indicated in Ch 7,3.5.1. are to be complied with. For the purposes of this comparison it is assumed that the stated shear properties of the proposed core material have been determined by use of the four point sandwich beam bending test ASTM C393 or equivalent.

1.13.10 Where the core shear stress, τ_c, determined from 1.13.9 is in excess of the limiting stress for a particular core material, the effective shear strength of the core material in the direction of the panel breadth, may be increased by the addition of shear ties. The effective shear strength, τ_{eff}, of the core material is to be determined from:

$$\tau_{eff} = \tau_c + \left(\frac{t_t}{s_t} \times \tau_t\right) \text{ N/mm}^2$$

where

τ_{eff} = effective shear strength of the core material, in N/mm^2

τ_c = shear strength of basic core material, in N/mm^2

t_t = thickness of shear tie material, in mm

τ_t = ultimate shear strength of the shear tie material, in N/mm^2

s_t = spacing or mean spacing of the shear ties, in mm, *see also* 1.13.11.

1.13.11 Where shear ties are to be fitted, the maximum spacing between the shear ties is to be not greater than the maximum panel breadth that can be achieved with the basic core material. Shear ties are also, in general, to be fitted in the sandwich structure beneath primary longitudinal members.

1.13.12 Shear ties fitted between the sandwich skins are to be angled at 45°. The width of shear tie bonding to the sandwich skins is to be $2{,}5t_c$ or 50 mm whichever is the greater, *see* Fig. 3.1.3.

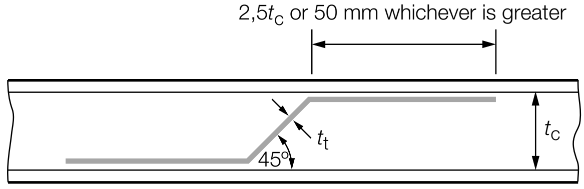


Fig. 3.1.3 Arrangement of shear ties

1.13.13 Shear ties may also be fitted between the webs of deep floors, transverses, girders and other primary stiffening members of top-hat type section. Such shear ties are to be spaced in accordance with the requirements of 1.16.2 and are to have a thickness of $t_w/3$ or 2 mm whichever is the greater, *see also* Ch 2,5.19.1 and LR's *Guidance Notes for Structural Detail*.

1.13.14 Where the Poisson's ratio, ν_f, for a particular facing laminate is known, the deflection, δ, of a flat sandwich panel with all edges assumed to be fully fixed, and subjected to a uniform lateral pressure is to be determined from:

$$\delta = \frac{p\,b^2}{8t_c}\left(\frac{b^2\,(1-\nu_f^2)}{24E_{ms}\,t_s\,t_c} + \frac{1}{G}\right) \times 10^{-3} \text{ mm}$$

where the mean skin modulus, E_{ms}, is given by:

$$E_{ms} = \frac{\Sigma\,(E_p\,t_s)}{\Sigma\,t_s} \text{ N/mm}^2$$

E_p is E_{tp} or E_{cp} whichever is the lesser.
where
ν_f, p, b, t_c, t_s, E_{tp}, E_{cp} and G are as defined in 1.5.1 and E_{ms} is the mean modulus of the total skin thicknesses.

1.13.15 Where the Poisson's Ratio, ν_f, for a particular facing laminate is not known, the deflection, δ, of a flat sandwich panel with all edges assumed to be fully fixed, and subjected to a uniform lateral pressure is to be estimated from:

$$\delta = \frac{p\,b^2}{8t_c}\left(\frac{b^2}{24E_{ms}\,t_s\,t_c} + \frac{1}{G}\right) \times 10^{-3} \text{ mm}$$

where
δ, p, b, t_c, t_s, and G, are as defined in 1.5.1
E_{ms} is as defined in 1.13.14.

1.13.16 The deflection determined from 1.13.14 or 1.13.15, as appropriate, is not to exceed the limiting deflection for the structural element under consideration, as indicated in Table 7.2.1 in Chapter 7.

1.14 Stiffeners general

1.14.1 Unless otherwise specified elsewhere in this Part, the Rule bending moment, M_s, to be applied to all stiffening members subjected to uniform lateral pressure is to be determined from:

$$M_s = \phi_M\, s\, l_e^2\, p \text{ Nm}$$

where
ϕ_M = bending moment coefficient as given in Table 3.1.5.

1.14.2 Unless otherwise specified elsewhere in this Part, the Rule shear force, F_s, to be applied to all stiffening members subjected to uniform lateral pressure is to be determined from:

$$F_s = \phi_s\, p\, s\, l_e \text{ N}$$

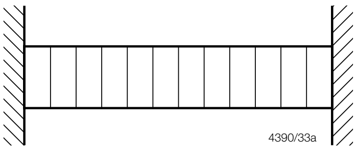
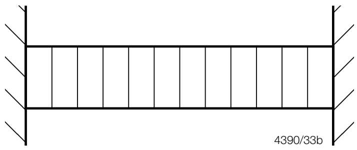
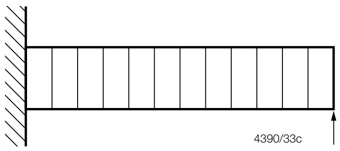
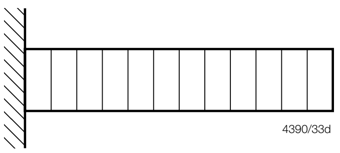
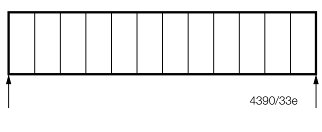
where
ϕ_S = shear force coefficient as given in Table 3.1.5.

1.14.3 The shear stress, τ_S, in the webs of stiffening members of 'top-hat' type section is to be determined from:

$$\tau_S = \frac{F_S}{2t_w\,d_W} \text{ N/mm}^2$$

where
F_S = shear force applied to the stiffening member, in *N*, as detailed in 1.14.2
t_W = stiffening member web thickness, in mm
d_W = stiffening member web depth, in mm. (Account is to be taken of the increased effective depth of web where the webs are inclined)

Table 3.1.5 Shear force, bending moment and deflection coefficients

Load model	Position			Position	Shear force, ϕ_S	Bending moment, ϕ_M	Deflection, ϕ_δ	Application
	1	2	3					
(a)				1 2 3	1/2 — 1/2	1/12 1/24 1/12	— 1/384 —	Primary and other members where the end fixity is considered encastre
(b)				1 2 3	1/2 — 1/2	1/10 1/10 1/10	— 1/288 —	Local, secondary and other members where the end fixity is considered to be partial
(c)				1 2 3	5/8 — 3/8	1/8 9/128 —	— 1/185 —	Various
(d)				1 2 3	1 — —	1/2 — —	— — 1/8	Various
(e)				1 2 3	1/2 — 1/2	— 1/8 —	— 5/384 —	Hatch covers, glazing and other members where the ends are simply supported

The maximum allowable shear stress is not to exceed that determined from Table 7.3.1 in Chapter 7, for the stiffener member under consideration.

1.14.4 The shear stress, τ_S, in the webs of stiffening members of inverted angle or 'T bar' type section is to be determined from:

$$\tau_S = \frac{F_S}{t_W\, d_W} \text{ N/mm}^2$$

where

F_S, t_W and d_W are as defined in 1.14.3.

The maximum allowable shear stress is not to exceed that determined from Table 7.3.1 in Chapter 7, for the stiffener member under consideration.

1.14.5 Unless otherwise specified elsewhere in this Part, the deflection, δ_S, of stiffening members, subjected to uniform lateral pressure is to be determined from:

$$\delta_S = \frac{\phi_\delta\, p\, s\, l_e^4}{(E\, I)_S} \times 10^5 \text{ mm}$$

where

$(EI)_S$ = total EI for the stiffener section including an effective width of attached plating as indicated in 1.7.1, in Ncm^4/mm^2

ϕ_δ = deflection coefficient as defined in Table 3.1.5

s, l_e, E, I and p are as defined in 1.5.1.

1.14.6 The maximum allowable deflection is not, in general, to exceed that determined from Table 7.2.1 in Chapter 7 for the stiffener member under consideration.

1.15 Geometric properties stiffener sections

1.15.1 The effective geometric properties of the stiffener sections are to be calculated directly from the dimensions of the section and associated effective width of attached plating in accordance with 1.7. Where the mean line of the stiffener webs is not normal to the attached laminate, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plate laminate. Where plywood, solid timber, aluminium alloy, steel or other materials are integrated into a stiffening member, the effectiveness of the material is to be determined in accordance with 1.20.3. The stress in the individual material is to be limited to the allowable strain associated with the constituent material.

1.15.2 The distance of the neutral axis, x_S, from the outer surface of the plate laminate is to be determined from:

$$x_S = \frac{\Sigma\,(E_i\, t_i\, b_i\, x_i)}{\Sigma\,(E_i\, t_i\, b_i)} \text{ mm}$$

where

E_i, t_i, b_i and x_i are as defined in 1.5.1.

1.15.3 The resultant extreme fibre tensile stress for an individual ply, σ_{ti}, is to be determined from:

$$\sigma_{ti} = \frac{0{,}1 E_{ti}\, y_i\, M}{\Sigma\,(EI)_S} \text{ N/mm}^2$$

where

σ_{ti}, E_{ti}, y_i, M, E_i and I_i are as defined in 1.5.1.

The term $(EI)_S$ refers to the whole stiffener section, i.e. including the attached plating in accordance with 1.7. *See also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*.

1.15.4 The resultant extreme fibre compressive stress for an individual ply, σ_{ci}, is to be determined from:

$$\sigma_{ci} = \frac{0{,}1 E_{ci}\, y_i\, M}{\Sigma\,(EI)_S}$$

where

σ_{ci}, E_{ci}, y_i, M, E_i and I_i are as defined in 1.5.1.

The term $(EI)_S$ refers to the whole stiffener section, i.e. including the attached plating in accordance with 1.7. *See also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*.

1.16 Stiffener proportions

1.16.1 From structural stability and local buckling considerations, the proportions of stiffening members are, in general, to be in accordance with the requirements of this Section.

1.16.2 The thickness of the web for 'top-hat' type stiffeners, t_w, is to be not less than that required to satisfy the web shear from 1.14.3 and 1.14.4, and in no case is to be taken as less than that determined from the following formula:

$$t_w = \frac{0{,}025 d_w + 1{,}1}{1{,}3 f_w + 0{,}61} \text{ mm}$$

where

d_w = unsupported web depth, in mm

f_w = fibre content, by weight, of the web laminate.

1.16.3 The thickness of the web of an inverted angle or 'T' bar stiffener section is to be twice the web thickness determined from 1.16.2.

1.17 Determination of span points

1.17.1 The effective span, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined from:

(a) For secondary stiffening members of top-hat type section as shown in Fig. 3.1.4(a) the span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member is equal to the depth of the member. Where there is no end bracket, the span point is to be measured between primary member webs.

(b) For primary stiffening members of top-hat type section as shown in Fig. 3.1.4(b) the span point is to be taken at the point where the depth of the end bracket, measured from the face of the primary stiffening member is equal to the half depth of the member. Where there is no end bracket, the span point is to be measured between primary member webs.

1.17.2 Where the stiffener member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

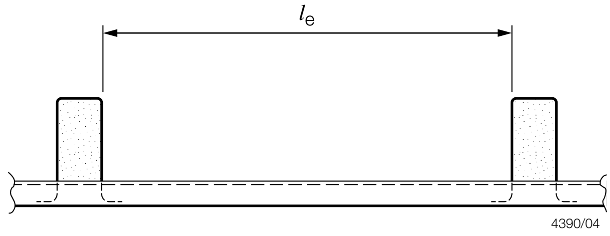


Fig. 3.1.4(a) Span points

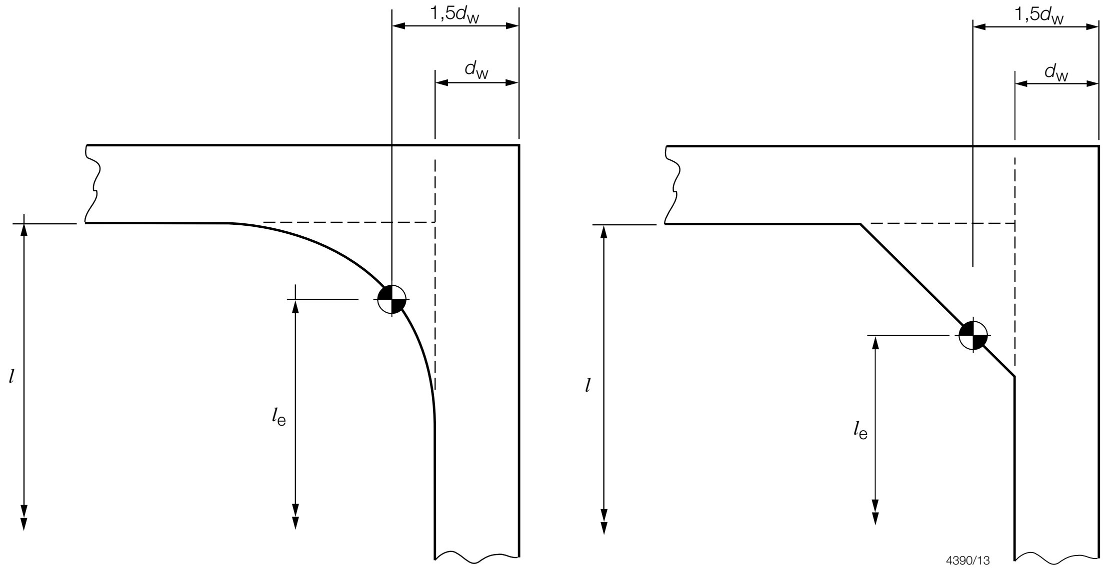


Fig. 3.1.4(b) Span points

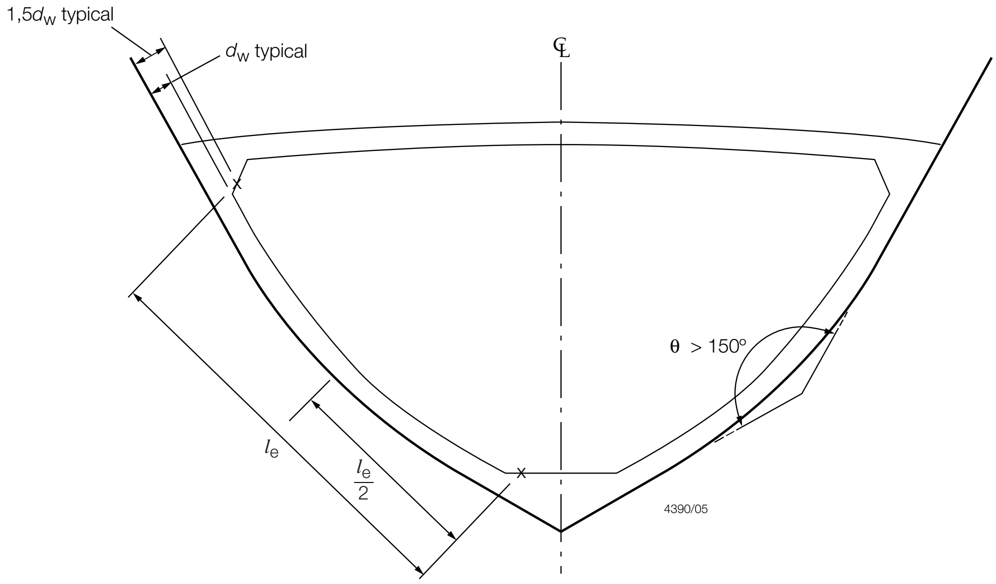


Fig. 3.1.4(c) Span points

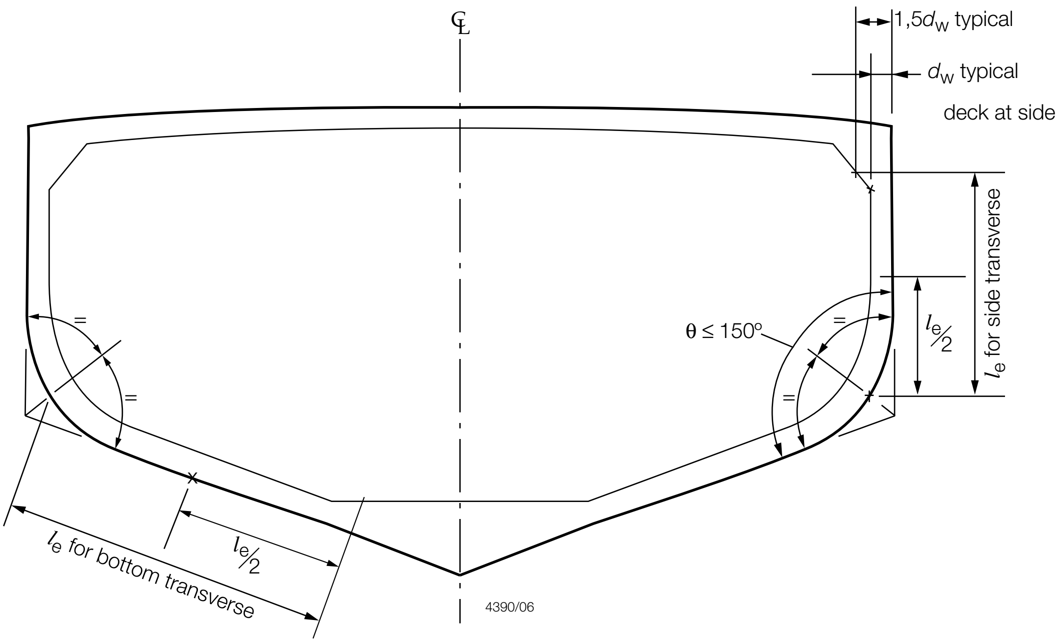


Fig. 3.1.4(d) Span points

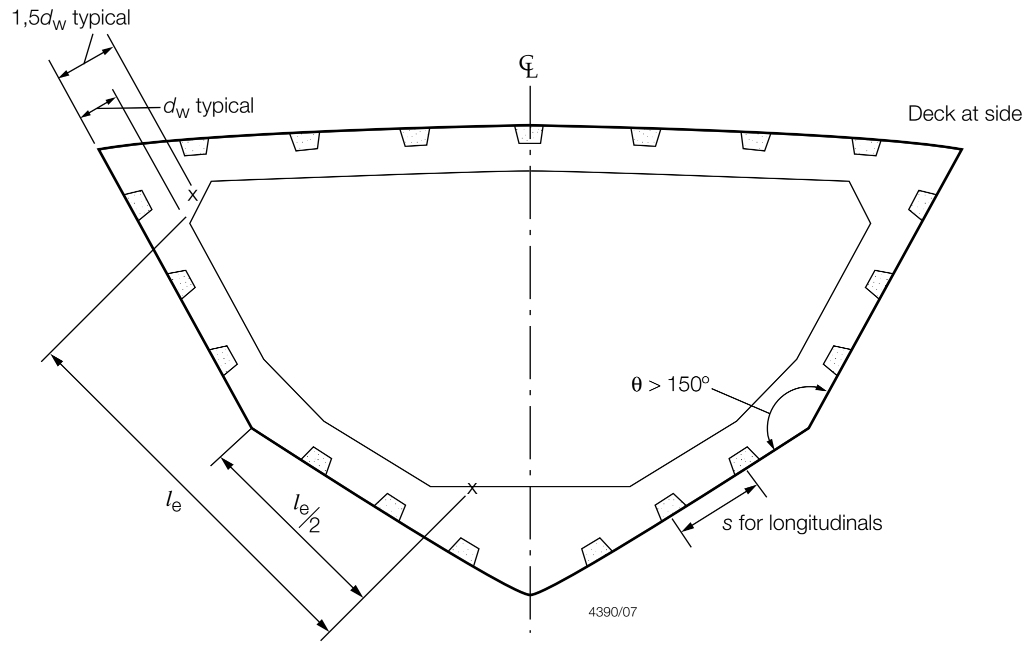


Fig. 3.1.4(e) Span points

1.17.3 Where the stiffening member is curved then the span is to be taken as the effective chord length.

1.17.4 Where there is a pronounced turn of bilge, chine or the structure is significantly pitched, the span is to be measured as in Fig. 3.1.4(c) to (f).

1.17.5 The determined effective span assumes that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, the span is to be determined excluding any effect from the end brackets.

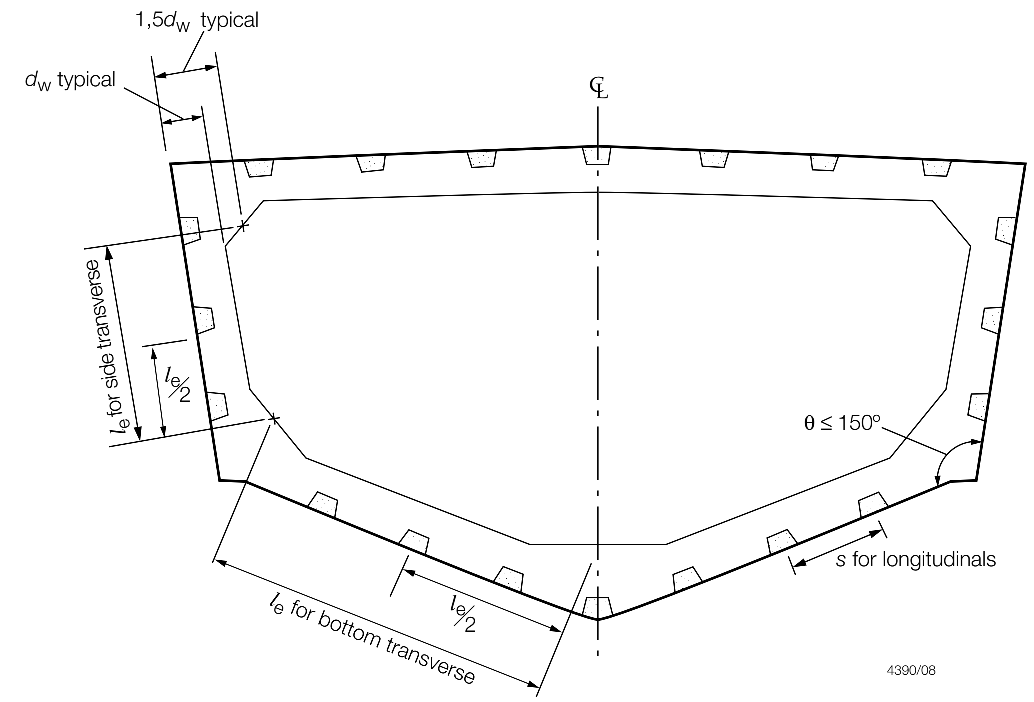


Fig. 3.1.4(f) Span points

1.18 Boundary bonding

1.18.1 The connection of the various laminates into assemblies and the connection of units to the main structure is generally to be made by means of single or double angles of the type shown in Fig. 3.1.5.

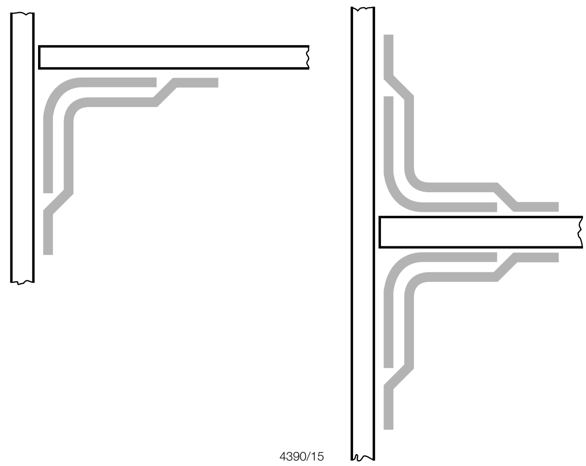


Fig. 3.1.5 Bonding angles

1.18.2 These matting-in angles are to be formed by layers of reinforcements, laid-up *in situ*, and normally secondary bonded to the structure before the laminates are advanced in cure. Where the laminating schedule is such that this cannot be achieved then suitable peel plies and secondary bonding techniques, as recommended by the resin manufacturer, *see* Ch 2,5.9, are to be arranged in way of the surfaces to be connected.

1.18.3 All surfaces to be bonded are to be clean and suitably prepared prior to the application of the bonding angles. Suitable fillets of compliant resin are to be arranged as shown in Figs. 3.1.6 and 3.1.7.

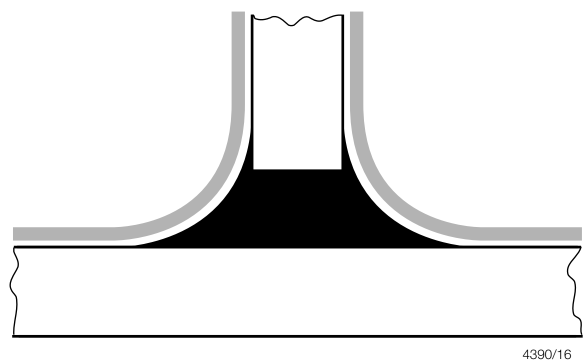


Fig. 3.1.6 Resin fillets

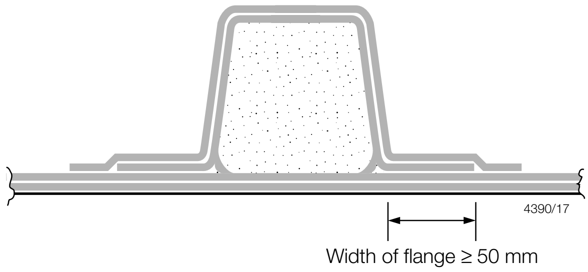


Fig. 3.1.7 Width of bonding angle

1.18.4 Where floors, bulkheads, tank boundaries, etc., are manufactured from plate laminate the weight of the laminate forming each angle is to be not less than 50 per cent of the weight of the lighter member being connected, or 900g/m^2 chopped fibre reinforcement or equivalent, whichever is the greater.

1.18.5 Double angles are normally to be used, but when this is not possible, such as where satisfactory access cannot be achieved on the reverse side, a single angle can be used provided it is suitably increased in width and weight. The weight of a single bonding angle is to be determined by direct calculation, and in no case to be taken as less than two thirds the weight of the lighter laminate being connected or 900 g/m^2 chopped fibre reinforcement or equivalent, whichever is the greater.

1.18.6 Where frames and stiffeners are of the 'top-hat' type, the width of the flange connection to the plate laminate is to be as shown in Fig. 3.1.7. The width of bonding angle is to be 25 mm for the first layer + 15 mm per each additional layer, but not less than 50 mm.

1.18.7 Where sandwich panels are to be connected the weight of bonding is to be not less than the weight of the appropriate skin. The inner and outer skins of primary sandwich structures such as bulkheads are to be effectively 'tied' by a suitable weight of reinforcement or by use of fillets and wedges of suitable compliant resin, as shown in Fig. 3.1.8.

1.18.8 Where the floors, bulkheads, etc., are manufactured from plywood the weight of the laminate forming each angle is to be not less than 50 per cent of the weight of the equivalent thickness of bulkhead in the material used for the bonding angle or the lighter member being connected.

1.18.9 In no case is the thickness of the double bonding angle to be less than 2 mm at a glass content, by weight, of 0,5. Where a glass content is less than 0,5, the thickness is to be not less than that required to resist the same shear force using the formulae in Tables 3.1.1 and 3.1.2.

1.18.10 Alternative bonding arrangements incorporating epoxy fillets, bonded wedges, bolting, etc., may be specially considered. It is however the responsibility of the Builder to demonstrate their suitability and equivalence to the Rule requirements.

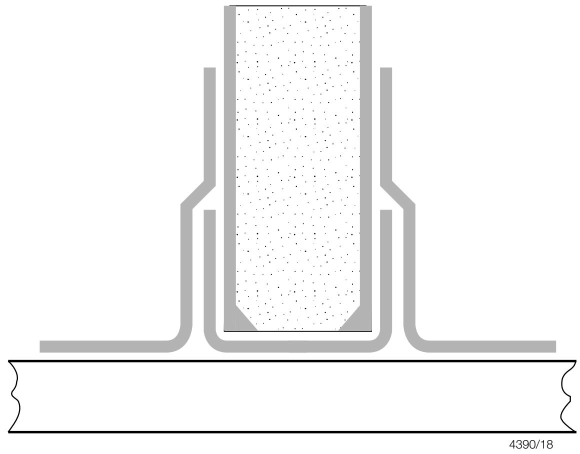


Fig. 3.1.8 Bonding ties

1.19 Timber

1.19.1 It is presumed that, in the selection of the species of timber for a particular application, the designers will relate the known characteristics, strength, density, bending and working capabilities of the particular species to the constructional design. The mechanical properties of timbers and assumptions used for design purposes are to be clearly indicated on the submitted construction plans, *see also* Ch 2,2.17 and 1.15.1.

1.19.2 All timbers are to be identified by their botanical name.

1.19.3 The moisture content of timber which is to be glued, bonded or overlaminated is to be about 15 per cent, *see also* Ch 2,2.17.

1.20 Plywood

1.20.1 Structural plywoods are to comply with Ch 2,2.17, *see also* Ch 2,2.16.3.

1.20.2 The mechanical properties of the plywood proposed for use in structural applications is to be obtained from the plywood manufacturer and submitted for consideration. In the absence of such data LR will estimate the mechanical properties based upon the recognised minimum expected strengths for the particular materials.

1.20.3 Where stiffeners incorporate encapsulated plywood structurally bonded to the plate laminate in accordance with 1.18.8, its effective $E_i I_i$ is to be incorporated into the $\Sigma (E_i I_i)$ as indicated in 1.15, with the basic thickness and tensile/ compressive moduli of the plywood being taken as those corresponding to the least effective over the span of the stiffener. Directional considerations for structural plywood incorporated in stiffening members are to be indicated on construction plans submitted for appraisal.

1.21 Aluminium alloy

1.21.1 The use of aluminium alloy is permitted for craft in accordance with Part 7. Where this material is to be integrated structurally, with the fibre composite structure, *see* Ch 2,2.15 and 1.15.1.

1.22 Steel

1.22.1 The use of steel is permitted for craft in accordance with Part 6. Where this material is to be integrated structurally, with the fibre composite structure, *see* Ch 2,2.15 and 1.15.1.

1.23 Other materials

1.23.1 Special consideration will be given to the use of other types of materials. Details of the type of material, the specification to which it was manufactured and its mechanical properties are to be submitted for appraisal, *see also* 1.15.1.

1.24 Secondary member end connections

1.24.1 Secondary members, i.e. longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure are, in general, to be connected at their ends in accordance with the requirements of this Section. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered on the basis of 1.17.5.

1.24.2 Where end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

1.24.3 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the scantlings of the brackets are to be such that their section properties and effective cross-sectional area are not less than those of the member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

1.24.4 The thickness of the bracket webs is to be not less than that required for the webs of the stiffening member. *See* 1.14.

1.24.5 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection are the properties reduced to less than that of the stiffener with associated plating.

1.24.6 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.24.7 Hard spots are to be avoided in way of end connections.

1.25 Scantlings of end brackets

1.25.1 Secondary members, i.e. longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are generally to be connected at their ends in accordance with the requirements of this Section. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered.

1.25.2 Where end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

1.25.3 The symbols used in this sub-Section are defined as follows:

t_w = the thickness of the bracket web, in mm
EI = section stiffness of the secondary member, in Ncm^4/mm^2

1.25.4 Typical arrangements of stiffener end brackets are shown diagrammatically in Fig. 3.1.9.

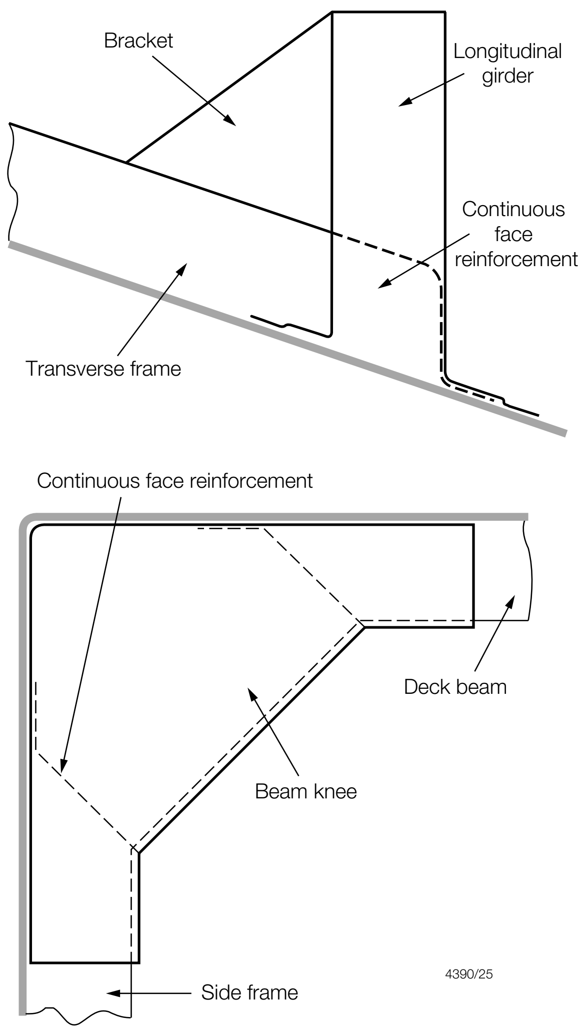


Fig. 3.1.9 Arrangement of end brackets

1.25.5 The section stiffness, (EI), in way of the bracket at the point to which the effective span of the stiffener, l_e, is measured is to be not less than two times the section stiffness of the basic stiffener.

1.25.6 The web thickness, t_w, and face width of end brackets are to be not less than that of the connecting stiffeners. Additionally the requirements of 1.16 are to be complied with.

1.25.7 Where brackets are of the inverted angle or 'T' bar stiffener section, their free edge is to be suitably stiffened by a flange or other equivalent means. The dimensions of the flange are to be such that the requirements of 1.16 are complied with.

1.25.8 Where the free edge of the bracket is hollowed out to form a 'soft-toe', the dimensions of the bracket arms and throat depth are to be increased such that the stiffness requirements of 1.16 are complied with.

1.26 Primary member end connections

1.26.1 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

1.26.2 The members are to have adequate lateral stability and web stiffening and the structure is to be so arranged as to minimize hard spots and other sources of stress concentration.

1.26.3 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

1.26.4 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended for at least two frame spaces, or equivalent, beyond the point of support before being tapered.

1.26.5 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening will, in general, be required.

1.26.6 The thicknesses of the bracket webs are, in general, to be not less than those of the primary member webs. Where brackets are of the plate type, the free edge of the bracket is to be adequately stiffened and the plate positioned to limit any hard spot.

1.26.7 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

1.26.8 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Proposals to fit brackets of reduced scantlings, or alternative arrangements, will be considered.

1.26.9 Connections between primary members forming a ring system are to minimize stress concentrations at the junctions. Integral brackets are generally to be radiused or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

1.27 Arrangements and details

1.27.1 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the section stiffness (EI), reduced to less than that of the stiffener with associated plating.

1.27.2 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.28 Web stability

1.28.1 Primary members of 'top-hat' or single plate laminate construction type section are to be supported by tripping brackets at, in general, four for top hat and alternate frame spacings for plate, of secondary stiffening members respectively.

1.29 Openings in the webs of stiffening members

1.29.1 Where openings are cut in the webs of stiffening members, the depth of the opening is not to exceed 50 per cent of the web depth, and the opening is to be so located that the edges are not less than 25 per cent of the web depth from the face laminate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered.

1.29.2 Openings are to have smooth edges and well rounded corners. Exposed edges in way of cut-outs in single skin/plate laminate are to be suitably sealed with resin and/or be over laminated. Exposed edges in way of cut-outs in sandwich panels and top hat type stiffening members are to be overlaminated with a weight of laminate not less than the lower of the two skins which form the panel (or stiffener) or 2 mm in thickness whichever is the greater.

1.29.3 Cut-outs for the passage of secondary members are to be arranged so as to minimize the creation of stress concentrations. To avoid excessive use of filler material the breadth of cut-out is to be kept as small as necessary and the fit as accurate as practicable. Suitable fillets are to be arranged to ensure efficient bonding.

1.29.4 Consideration is to be given to the provision of adequate drainage and unimpeded flow of air and water when designing the cut-outs and connection details.

1.30 Continuity and alignment

1.30.1 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

1.30.2 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment.

1.30.3 Pillars and pillar bulkheads are to be fitted in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

1.30.4 Continuity is to be maintained where primary members intersect and where the members are of the same depth, *see also* LR's *Guidance Notes for Structural Details*.

1.30.5 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

1.30.6 The toes of brackets, etc., are not to land on un-stiffened panels of plating. Special care is to be taken to avoid notch effects at the toes of brackets, by making the toe concave or otherwise tapering it off in accordance with Fig. 3.4.1 in Chapter 3.

1.31 Arrangements at intersection of continuous secondary and primary members

1.31.1 Cut-outs for the passage of secondary members through the webs of primary members, and the related bonding arrangements, are to be so designed as to minimize stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating. The critical shear buckling stress of the panel in which the cut-out is made is to be examined. Longitudinals will be required to have double bonding angles which may require to be locally increased in weight in areas of high stress, such as under bulkheads, machinery seating, mast steps, etc. The increased shear stresses in these areas are to be examined.

1.31.2 It is recommended that the web plate connection to the hull envelope, or bulkhead end in a smooth tapered 'soft toe'. Recommended shapes of cut-out are shown in Fig. 3.4.1, but consideration will be given to other shapes on the basis of maintaining equivalent strength and minimizing stress concentration.

1.31.3 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

■ *Section 2* Minimum thickness requirements

2.1 General

2.1.1 Structural laminates, used for both single skin and sandwich construction are, in general, to incorporate not less than 40 per cent, by weight, of woven or cross-ply reinforcement.

2.2 Single skin laminate

2.2.1 The minimum thicknesses of single skin laminates are as indicated in the appropriate Sections.

2.3 Sandwich skin laminate

2.3.1 The minimum thicknesses of single skin laminates which form the inner and outer skins of sandwich panels are as indicated in the appropriate Sections. Where the structural requirements for thickness of either the bottom shell outer skin, or inner skin in way of an integral tank, is less than 4,5 mm, the acceptance of thicknesses down to a minimum of 3,5 mm will be subject to a vacuum test to demonstrate the watertight integrity and also an impact test for impact resistance of the laminate, *see* 2.8.2.

2.4 Laminate thickness of single and sandwich skin laminates

2.4.1 The Rule minimum skin thicknesses as determined from the appropriate Sections of the Rules are to be corrected for craft type irrespective of the reinforcement being used; the corrected minimum skin thickness of side, bottom, transom, wet-deck, vehicle deck and weather decks is to be determined from:

Single skin laminates:

$$t_T = \omega\, t_{min}$$

Sandwich skin laminates:

$$t_{min} = 2\omega$$

where

ω = Service Type Correction Factor given in Table 3.2.1
t_T = Rule minimum thickness corrected for craft type, in mm.

Table 3.2.1 Service type correction factor (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,00
Patrol	1,00
Pilot	1,1
Yacht	1,00
Workboat – Motor fishing vessel	1,2

2.4.2 All minimum thicknesses of laminate for both stiffener and laminate components are based on an assumed fibre content, f_c, of 0,5. Where the fibre content by weight, f_c, is less than 0,5, the required minimum thicknesses are to be determined from:

$$t_{fc} = t_{0,5}\,(1{,}65 - 1{,}3f_c) \text{ mm}$$

where

t_{fc} = minimum thickness at actual laminate fibre content, in mm

$t_{0,5}$ = Rule basic minimum laminate thickness at fibre content, by weight, of 0,5.

2.4.3 The equation in 2.4.2 relates to polyester 'E' glass laminates. Other laminates will be considered on an equivalence basis.

2.5 Integral tank structure

2.5.1 The minimum thickness of laminate for all stiffening members passing through, or forming the boundary of integral oil fuel and water tanks is to be not less than 4,5 mm irrespective of fibre content.

2.5.2 Where the boundaries of integral oil fuel and water tanks are of sandwich skin construction the minimum thickness of the laminate providing the fluid barrier, without satisfactory material testing, is to be not less than 4,5 mm, *see* 2.3.1.

2.5.3 Where the boundaries of integral oil fuel and water tanks are of single skin construction, in no case is the tank laminate thickness, determined in accordance with 7.4, to be less than 5,0 mm irrespective of fibre content.

2.6 Local reinforcement

2.6.1 The hull and deck are to be locally increased in thickness in way of fittings for rudder tubes, propeller brackets, passenger routes, vehicle lanes, etc. The increase in thickness is to be not less than 50 per cent of the thickness of the adjacent plate laminate. Details of such reinforcement are to be submitted for consideration, *see also* Ch 2,3.9.

2.6.2 Local reinforcement is in general to extend under the adjacent supporting structure and then be tapered gradually to the base laminate thickness over a distance not less than 20 times the difference in thickness, *see* Fig. 3.2.1.

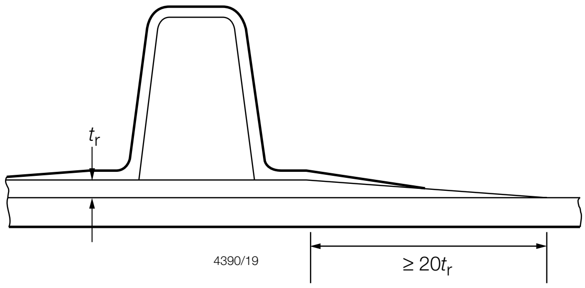


Fig. 3.2.1 Arrangement of local reinforcement

2.6.3 The amount of material laid 'wet on wet' is to be limited to avoid excessive heat generation.

2.6.4 Where a superstructure is fitted, the side shell plating, in way of the end of the superstructure, may be required to be increased in thickness.

2.7 Novel features

2.7.1 Where the Rules do not specifically define the requirements for novel features, the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted with the relevant construction plans for appraisal, *see also* Ch 1,2.6.

2.8 Impact considerations

2.8.1 Due consideration is to be given to the scantlings of all structures which may be subject to local impact loadings. Impact tests may be required to be carried out at the discretion of LR to demonstrate the suitability of the proposed scantlings for a particular application.

2.8.2 The minimum skin thickness requirements may, subject to the agreement of LR, be reduced provided that suitable impact tests are carried out to demonstrate that the proposed laminates have not less than the equivalent impact resistance to that of a laminate which satisfies the Rule minimum thickness. In addition it is assumed that this reduced laminate satisfies the structural strength and deflection requirements of the Rules.

2.9 Sheathing

2.9.1 Areas of shell and deck which are subject to additional wear by abrasion e.g. passenger routes, working areas of fishing craft, forefoot region, etc, are to be suitably protected by local reinforcement or sheathing. This sheathing may be of timber, rubber, steel, additional layers of reinforcement, etc., as appropriate. Details of such sheathing and the method of attachment are to be indicated on the relevant construction plans submitted for appraisal.

2.9.2 The attachment of sheathing by mechanical means such as bolting or other methods is not to impair the structural integrity of the laminate or the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable. The design arrangements in way of any through bolting is to be such that damage to the sheathing will not impair the watertight integrity of the attachment to the hull.

■ *Section 3* Shell envelope laminate

3.1 General

3.1.1 The requirements in respect of the general plating elements of the shell envelope, excluding the deck, are contained within this Section.

3.2 Keel plate

3.2.1 The width, b_K, and thickness, t_K, of plate keels are not to be taken as less than:

$$b_K = 7{,}0L_R + 340 \text{ mm}$$

$$t_K = \sqrt{k_t}\,(5{,}0L_R^{0{,}45}) \text{ mm}$$

where

$$k_t = \frac{152}{\sigma_f}$$

L_R = Rule length, in metres, as defined in 1.5.1

σ_f = ultimate flexural strength of the keel plate material, in N/mm^2, *see* 1.12.6.

3.2.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of plate keels are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard measured at the forward perpendicular (FP), above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by 3.3 for the stem. Laminate tapers are to be in accordance with Ch 2,3.9.

3.2.4 Where the bottom shell is of sandwich construction the keel is, in general, to be formed by locally returning to single skin construction for a width as required by 3.2.1. The Rule thickness of keel is to comprise both the inner and outer skins of the adjacent bottom shell sandwich plus additional reinforcement as required. The distribution of reinforcement in way of the plate keel and sandwich bottom structure is to be in accordance with Fig. 3.3.1.

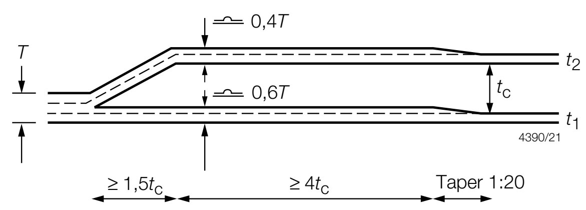


Fig. 3.3.1
Single skin/sandwich skin intersection detail

3.2.5 For large or novel craft, or yachts with externally attached ballast keels, or where it is proposed to incorporate keels of the 'bar' type the scantlings of the keel will be specially considered.

3.3 Stem plate

3.3.1 The thickness of the plate stem, t_s, is not to be taken as less than that given by the following expression:

$$t_s = \sqrt{k_t}\,(0{,}29L_R + 9) \text{ mm}$$

where

k_t = as defined in 3.2.1

L_R = Rule length, in metres, as defined in 1.5.1

σ_f = ultimate flexural strength of the stem plate material, in N/mm^2, *see* 1.12.6.

3.3.2 In no case is the thickness of the plate stem to be taken as less than the thickness of the adjacent side shell plating.

3.3.3 The width of the plate stem is to be not less than the width of keel as required by 3.2.1.

3.3.4 Plate stems are to be supported by horizontal diaphragms and, where the stem radius is large, a centreline stiffener or web may be required.

3.3.5 Where the side shell is of sandwich construction the stem is to be formed by locally returning to single skin construction for a width as required by 3.2.1. The Rule thickness of stem is to comprise both the inner and outer skins of the adjacent side shell sandwich plus additional reinforcement as required. The distribution of reinforcement in way of the plate stem and sandwich bottom structure is to be in accordance with Fig. 3.3.1.

3.3.6 For large or novel craft, the scantlings of the stem will be specially considered, *see also* 5.11.

3.4 Bottom

3.4.1 The bending moment assumed to be carried by the bottom shell plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for high speed or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.4.2 and 3.4.4 respectively.

3.4.2 An estimate of the thickness of **bottom single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.4.3 In no case is the minimum thickness of single skin plating to be taken as less than 5,5 mm.

3.4.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **bottom sandwich panel** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.4.5 In no case are the minimum thicknesses of laminate which form the skins of a sandwich laminate to be taken as less than 4,5 mm and 3,5 mm for the outer and inner skins respectively, *see also* 2.3.1.

3.4.6 For all craft types, the minimum bottom shell thickness as required by 3.4.3 and 3.4.5 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.4.7 Additionally, for high speed craft, the minimum thickness requirements for the bottom shell between the bilge tangential points or chines and the chine line or 150 mm above the static load waterline, whichever is the greater, is not to be less than determined for the side shell using the side shell impact pressure or the bottom shell hydrostatic or pitching pressures associated with a displacement or semi-displacement type craft whichever is the greater, *see* Fig. 3.3.2.

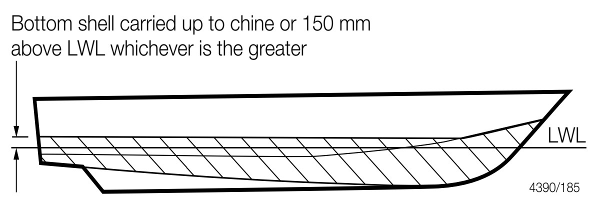


Fig. 3.3.2 Extent of bottom shell

3.4.8 Special consideration may be given to laminate thicknesses lesser than those required by 3.4.2 and 3.4.4, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

3.5 Side

3.5.1 The bending moment assumed to be carried by the side shell plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.5.2 and 3.5.4 respectively.

3.5.2 An estimate of the thickness of **side single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.5.3 In no case is the minimum thickness of single skin plating to be taken as less than 5 mm.

3.5.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **side sandwich panel** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.5.5 In no case are the minimum thicknesses of laminate which form the skins of a sandwich laminate to be taken as less than 4 mm and 3 mm for the outer and inner skins respectively.

3.5.6 Special consideration may be given to laminate thicknesses lesser than that required by 3.5.3 and 3.5.5, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

3.6 Sheerstrake

3.6.1 The sheerstrake, is in general, to be taken as the side shell, locally reinforced in way of deck/hull connection and fender attachment. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service, but is not to be less than that required by 2.6.

3.6.2 The fendering arrangements for all craft types are the responsibility of the designers/Builders and are outside the scope of classification.

3.6.3 Where the pressure or impact loadings that a particular type of craft will experience in service are considered by the Builder, or subsequent Owner, to be not covered by, or be greater than, those indicated in Part 5 of the Rules, details of the loadings together with the calculations of how these will be satisfactorily distributed into the craft's structure, are to be submitted for consideration with the relevant construction plans.

3.6.4 The arrangements indicated in 3.6.5, 3.6.6, 4.19.5 and 4.19.6 for pilot and fishing craft are for the guidance of the Builder and subsequent Owners/operators of the craft. Where the intended service for either of these types of craft, or other types of craft which may be subject to loadings resulting from contact with other craft, jetties or similar loading or boarding facilities, is such that the loadings are greater than those that can be satisfactorily distributed into the craft's structure by the arrangements indicated, the strengthening arrangements are to be increased accordingly.

3.6.5 For **pilot craft** and other general workboats which may be subject to repeated impact loadings from contact with other craft, etc., the sheerstrake laminate and stiffening arrangements in way are to be increased locally. An increase in laminate weight of not less than 50 per cent of the side shell laminate weight is to be fitted, extending in general from the bow aft over a distance of $0{,}33L_R$ or 500 mm aft of the point at which the craft reaches its greatest breadth, whichever is the greater, and around the quarters. The additional weight is to extend forward of the quarter and over the transom for a distance of $0{,}075L_R$ or 1,0 m, whichever is the greater. This reinforcement is in general to extend from the deck edge to below the first longitudinal stiffener, or a vertical distance equivalent to 1/3 the freeboard height, whichever is the greater. The additional laminate weight is then to be tapered out to the side shell laminate weight in accordance with the Rules, *see* 3.14.2. For increase in stiffening arrangements, *see* 4.19. Where the side shell is of sandwich construction then in way of the sheerstrake the two skins of the sandwich are to combine and form a single skin. The weight of this single skin is to be the Rule single skin reinforced in accordance with the above or 1,5 times the total sandwich skin laminate weight whichever is the greater. The arrangement and distribution of this additional laminate between the skins in way of the taper is to be in accordance with 3.2.4. Where fendering can be considered to act as a chine/spray rail the extent of bottom shell laminate is, in general, to be to above the lower fender.

3.6.6 **Fishing craft** are, in general, to have their shell laminate as required to satisfy the Rule loadings, increased by 20 per cent. Additionally the side shell is not to be taken as less than the bottom shell weight, and where there are gallows, gantries, nets, or lines, etc., the laminate in way is to be further increased locally and/or suitably protected by sheathing in timber, steel or other means. Where the hull is of sandwich construction in way of the sheerstrake the laminate is to combine to form a single skin as indicated in 3.6.2.

3.6.7 Individual consideration will be given to lesser scantlings than those required by 3.6.3. for fishing craft used for pleasure, light duties, etc. Details of the service are to be submitted for appraisal.

3.7 Transom boundary reinforcement

3.7.1 Additional reinforcement is to be moulded into the transom boundary.

3.7.2 For single skin construction, the total weight of reinforcement is to be not less than twice the weight of the adjacent side shell plate laminate, but need not be greater than Rule keel weight as required by 3.2.

3.8 Chine reinforcement

3.8.1 Additional reinforcement is to be moulded into the chine line knuckle boundary, chines and other areas where there is a change of section.

3.8.2 The chine line knuckle is to be reinforced as required by 3.7 for the transom boundary.

3.8.3 Chine details are to be such that the continuity of structural strength across the panel is maintained. Details of all chines are to submitted for consideration, *see also* LR's *Guidance Notes for Structural Details*.

3.9 Skeg

3.9.1 The thickness of the skeg plating is, in general, to be not less than the thickness of the keel at bottom or 1,5 times the thickness of the bottom shell on the sides, whichever is the greater, *see also* 5.10.

3.10 Shell openings

3.10.1 Openings are to have smooth edges and well rounded corners. Exposed edges in way of cut-outs in single skin/plate laminate are, in general, to be suitably sealed over laminating with not less than 2 x 450 g/m^2 CSM (or equivalent) reinforcements. Alternative arrangements demonstrating the equivalent protection to the ingress of moisture into the laminate will be individually considered in association provided on the relevant plans.

3.10.2 The exposed edges of all openings cut in sandwich panels are to be suitably sealed. In general a high density foam core (or equivalent material) is to be used around the perimeter of such openings. Exposed edges in way of cut-outs in sandwich panels are to be overlaminated with a weight of laminate not less than that required for the outer skin of the sandwich panel.

3.10.3 Where other than an epoxy resin system is used the first layer of reinforcement, as required by 3.10.1 and 3.10.2, is, in general, to be CSM with a weight not exceeding 300 g/m^2.

3.10.4 Sea inlet boxes are to have well rounded corners and, so far as possible are to be kept clear of the bilge radius. Arrangements are to be made to maintain the continuity of structural strength in way of the openings.

3.11 Appendages

3.11.1 The scantlings of appendages will be subject to special consideration on the basis of the Rules and the design loadings anticipated, but are in no case to be taken as less than that of the surrounding structure.

3.12 Fin and tuck

3.12.1 Additional reinforcement is to be moulded into the fin and tuck areas of yachts which have either internal fixed ballast or external attached ballast keels, *see also* Part 16.

3.12.2 For single skin construction the total weight of reinforcement is not to be less than 1,50 times the weight of the adjacent bottom shell plate laminate, but need not be greater than the Rule keel weight as required by 3.2.

3.13 Transom

3.13.1 The thickness of the stern or transom is to be not less than that required by 3.4 and 3.5 as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.14 Local reinforcement

3.14.1 The hull is to be locally increased in thickness in way of fittings for rudder tubes, propeller brackets, etc. The amount of increase is to be not less than 50 per cent of the adjacent plate laminate. Details of such reinforcement are to be submitted.

3.14.2 Local reinforcement is in general to extend under the adjacent supporting structure and then be tapered gradually to the base laminate thickness over a distance of not less than 20 times the difference in thickness, *see* 2.6.

3.15 Hull laminate arrangement

3.15.1 The hulls of all craft with a service speed of 25 knots or greater are to be moulded, such that following local impact, damage progressive stripping of surface reinforcements will not occur. This may be achieved by arranging all hull reinforcements as shown in Fig. 3.3.3.

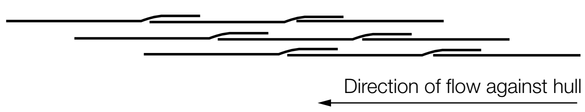


Fig. 3.3.3 Arrangement of hull reinforcement

3.15.2 Details of the laminate sequence and direction of orientation are to be indicated in the laminate schedule as required by Ch 2,3.3.7.

3.15.3 It is recommended that woven reinforcements be laid transversely to minimise the susceptibility to progressive stripping of hull laminates following local impact.

3.15.4 Special consideration is to be given to hull laminates where high glass content is proposed and where orthophthalic resins are used.

3.16 Novel features

3.16.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for appraisal.

■ *Section 4* Shell envelope framing

4.1 Application

4.1.1 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 General

4.2.1 To determine the required scantlings, the formulae indicated in 1.14 are, in general, to be used in conjunction with the design loadings specified in Part 5.

4.3 Symbols and definitions

4.3.1 Symbols and definitions for use throughout this Chapter are as given in 1.5.1 or specified in the appropriate Section.

4.4 Bottom longitudinal stiffeners

4.4.1 The bottom longitudinals are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.4.2 Bottom longitudinals are to be continuous through the supporting structures.

4.4.3 Where it is impracticable to comply with the requirements of 4.4.2, or where it is desired to terminate the bottom longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.4.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b).

4.4.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.5 Bottom longitudinal primary stiffeners

4.5.1 Bottom longitudinal primary stiffeners are to be supported by bottom deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.5.2 Bottom longitudinal primary stiffeners are to maintain their continuity through the supporting structures.

4.5.3 Where it is impracticable to comply with the requirements of 4.5.2, or where it is desired to terminate the bottom longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.5.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

4.5.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.6 Bottom transverse stiffeners

4.6.1 Bottom transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.6.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b).

4.6.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.7 Bottom transverse frames

4.7.1 Bottom transverse frames are defined as stiffening members which support the bottom shell, they are to be effectively continuous and be bracketed at their end connections to side frames and bottom floors as appropriate.

4.7.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

4.7.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.8 Bottom transverse web frames

4.8.1 Bottom transverse web frames are defined as primary stiffening members which support bottom shell longitudinals, they are to be continuous and be substantially bracketed at their end connections to side web frames and bottom floors.

4.8.2 Where it is impracticable to comply with the requirements of 4.8.1, or where it is desired to terminate the bottom transverse web frames in way of bulkheads or integral tank boundaries, etc., they are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed', *see* Fig. 3.4.1 and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.8.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

4.8.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.9 Side longitudinal stiffeners

4.9.1 The side longitudinals are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.9.2 Side longitudinals are to be continuous through the supporting structures.

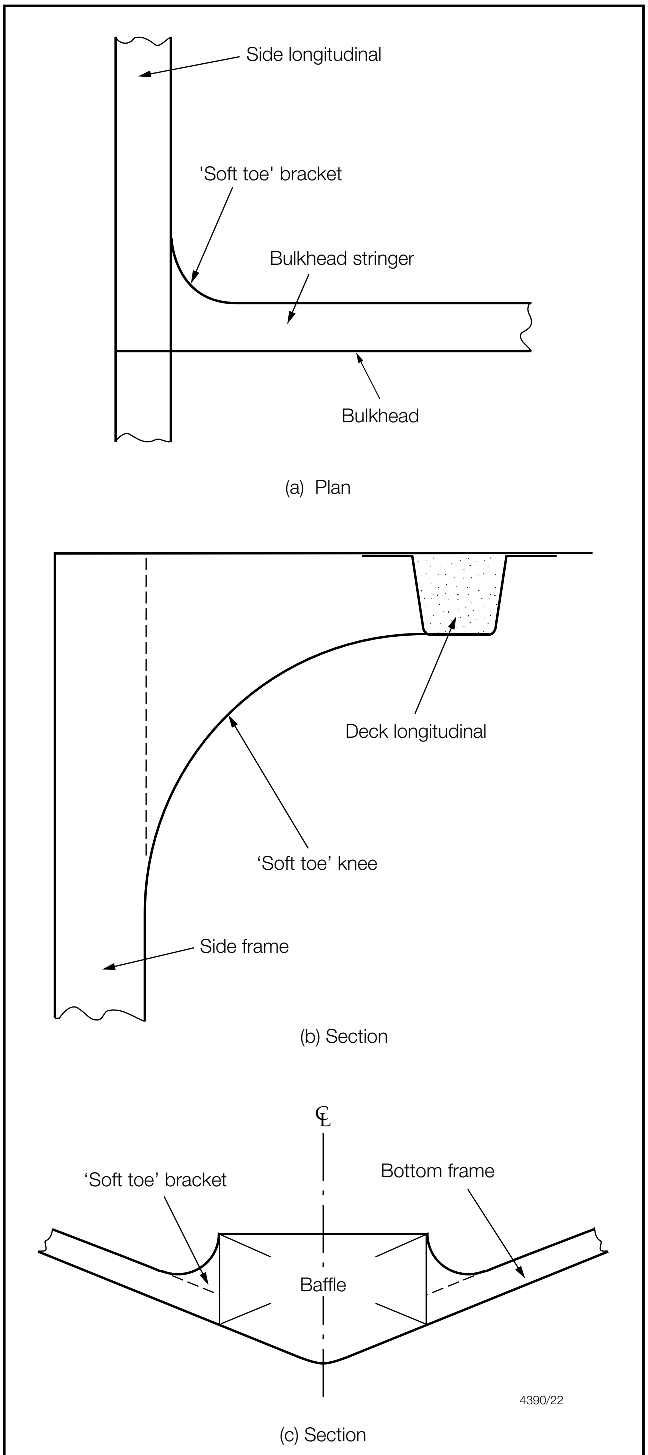


Fig. 3.4.1 'Soft-toe'

4.9.3 Where it is impracticable to comply with the requirements of 4.9.2, or where it is desired to terminate the side longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.9.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b).

4.9.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.10 Side longitudinal primary stiffeners

4.10.1 Side longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.10.2 Side longitudinal primary stiffeners are to maintain their continuity through the transverse bulkheads and other supporting structures.

4.10.3 Where it is impracticable to comply with the requirements of 4.10.2, or where it is desired to terminate the side longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.10.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

4.10.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.11 Side transverse stiffeners

4.11.1 Side transverse stiffeners are defined as local stiffening members which support the side shell, and which may be continuous or intercostal.

4.11.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b).

4.11.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.12 Side transverse frames

4.12.1 Side transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.12.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

4.12.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.13 Side transverse web frames

4.13.1 Side transverse web frames are defined as primary stiffening members which support side shell longitudinals, they are to be continuous and be substantially bracketed at their head and heel connections to deck beams and bottom web frames respectively.

4.13.2 Where it is impracticable to comply with the requirements of 4.13.1, or where it is desired to terminate the side transverse web frames in way of side longitudinal primary stiffeners, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections,to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.13.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

4.13.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.14 Grouped frames

4.14.1 For the purposes of satisfying Rule requirements, frames may, subject to agreement by LR, be grouped. The number of frames in any group shall not in general exceed five. The summation of section stiffness, EI, for the group of frames is not to be less than the summation of the Rule requirements for the individual framing members. In addition, in no case is the proposed scantlings of an individual framing member within the group to be less than ninety per cent of the Rule value for that member.

4.15 Grillage structures

4.15.1 For complex girder systems, a complete structural analysis using numerical methods may have to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended, *see also* 1.3.

4.15.2 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

4.15.3 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

4.16 Combined framing systems

4.16.1 Where longitudinal and transverse primary stiffeners form grillage structures the scantlings may be derived in accordance with 4.15.

4.17 Floating framing systems

4.17.1 Where the floating frame system is used, the effect of the plating attached to the stiffening members is to be ignored when calculating the required section stiffness, EI, of the primary stiffening members, i.e. the full section stiffness, EI, is to be provided by the primary stiffening member only.

4.18 Frame struts

4.18.1 Where struts are fitted to side shell transverse web frames or longitudinal primary stiffeners to carry axial loads the strut cross-sectional area is to be derived as for pillars in Section 10. If fitted at the stiffener half span point the stiffener section modulus may be taken as half the modulus derived from the general equations for the stiffening member being considered.

4.18.2 Design of end connections is to be such that the strut loads can be efficiently transmitted into the supporting structure.

4.19 Fenders and reinforcement in way

4.19.1 The design of and responsibility for the fendering on any craft rests with the designer and prospective Owner and are outside the scope of classification scantling approval requirements. The arrangement for fendering fitted should not be detrimental to the general working of the structure and therefore the requirements indicated in 4.19.2 to 4.19.6 are provided as recommendations of the areas requiring special consideration by the designer and Builder.

4.19.2 Wood belting and fenders, which may be subject to considerable impact load, are to be bedded down on a flexible sealing compound or a neoprene type gasket to ensure watertightness. The bolts are to be both adequate in number and size and, where practicable, reeled to prevent perforation of the laminate. Substantial plate washers or, where practicable, a continuous backing plate are to be provided. The arrangement for the attachment of the fender should, in general, be arranged so that where sections of the fender are damaged or torn, the watertight integrity of the hull is not impaired.

4.19.3 The laminate in way of such fittings is to be substantially increased in thickness to prevent overloading, and depending on the position, a back-up block of wood, plastic or metal may be required.

4.19.4 For craft such as pilot craft, fishing craft, etc., which may be subject to repeated impact loadings from contact with other craft whilst in service, due consideration is to be given to increasing the scantlings of stiffening members in way of the fenders. Details of these increased scantlings, anticipated loadings and calculations, are to be indicated on the submitted plans, *see also* 3.6.3 and 3.6.4.

4.19.5 **Pilot craft** are, in general, to be fitted with large knees in way of the sheerstrake in areas as indicated in 3.6.5. The knees are to be aligned between the transverse frames and the deck beams. In the case of longitudinally framed craft, intermediate web frames with knees are to be fitted at a spacing of generally not greater than 500 mm. A side longitudinal with a section modulus of in general, twice that of the Rule longitudinal for the web frame spacing is to be positioned just below the lower fendering to carry the load associated with the dynamic loading from pitching and rolling. Consideration is also to be given to the termination of such brackets by use of a 'soft-toe' in way of the deck. The thickness of the webs for these knees is to be twice that required by 1.16 or 6 mm at a fibre content by weight, of 0,5. Where the fibre content is less than 0,5 the minimum thickness is to be increased by the factor k_c as follows:

$$t_{min} = 6k_c$$

where

k_c = 1,65 – 1,3f_c

f_c is as defined in 1.5.1.

4.19.6 **Fishing craft** engaged in pair trawling and other modes of fishing, and which may be subject to repeated impact loading from contact with the other craft, are to have additional stiffening fitted in way of the impact areas. This may be in the form of large knees, intermediate knees or substantial fendering/rubbing strakes. Additionally, the shell and deck in way of all working areas are to be suitably sheathed.

Section 5
Single bottom structure and appendages

5.1 General

5.1.1 The requirements of this Section provide for single bottom construction of mono-hull craft in association with either transverse or longitudinal framing.

5.1.2 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity particularly in way of skegs. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

5.1.3 Particular attention is to be taken to ensure that the continuity of structural strength in way of the intersection of transverse floors and longitudinal girders is maintained. The face reinforcement of such stiffening members is to be effectively continuous.

5.1.4 The single bottom structure in way of the keel, skeg and girders is to be sufficient to withstand the forces imposed by dry-docking the craft.

5.1.5 The breadth and thickness of plate keels are to comply with the requirements detailed in 3.2. *See also* 3.9.1.

5.2 Centreline girder

5.2.1 In craft with single bottoms, a centreline girder is, in general, to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.2.2 Centreline girders may be in the form of intercostal or continuous top hat or plate webs. Where the girder is intercostal, additional bracketing and local reinforcement is to be provided to maintain the continuity of structural strength. The face reinforcement in all cases is to be continuous.

5.2.3 The web depth of the centre girder in general is to be equal to the depth of the floors at the centreline as specified in 5.4.

5.2.4 The web thickness, t_w, for a centre girder of 'top-hat' type section is to be not less than that required by 1.16. or as determined as follows, whichever is the greater:

$$t_w = 1,28\sqrt{k_A}\left(\sqrt{L_R} + 1\right) \text{ mm}$$

in no case is t_w to be taken less than 5,0 mm

where

k_A and L_R are as defined in 1.5.1.

5.2.5 The web thickness for a centre girder of single plate laminate construction is to be two times the thickness as required by 5.2.4.

5.2.6 The face area of the centre girder, A_f, is to be not less than:

$$A_f = 1,18 L_R k_A \text{ cm}^2$$

where
k_A and L_R are as defined in 1.5.1.

5.2.7 The face area of the centre girder outside 0,5*L* about midships may be reduced to 80 per cent of the value given in 5.2.6.

5.2.8 The face thickness, t_f, is to be not less than the web thickness of the centre girder.

5.2.9 Additionally, the requirements of 4.5 for bottom longitudinal primary stiffeners are to be complied with.

5.3 Side girders

5.3.1 Where the floor breadth at the upper edge exceeds 6,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders, where fitted, are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.3.2 In the engine room, additional side girders are generally to be fitted in way of the main machinery.

5.3.3 The face area of side girders, A_f, is not to be taken as less than:

$$A_f = 0{,}82 L_R \, k_A \text{ cm}^2$$

where
k_A and L_R are as defined in 1.5.1.

5.3.4 The face thickness, t_f, is not, in general, to be less than the web thickness of the side girder.

5.3.5 The web thickness, t_w, for side girders of 'top-hat' type section is to be not less than as required by 1.16 or as determined as follows, whichever is the greater:

$$t_w = 1{,}28\sqrt{k_A L_R} \text{ mm}$$

where
k_A and L_R are as defined in 1.5.1
in no case is t_w to be taken less than 5,0 mm.

5.3.6 The web thickness for side girders of single plate laminate construction is to be two times the thickness as required by 5.3.4.

5.3.7 In addition, the requirements of 4.5 for bottom longitudinal primary stiffeners are to be complied with.

5.3.8 Watertight side girders, or side girders forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3. and 7.4 respectively.

5.4 Floors, general

5.4.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.4.2 In longitudinally framed craft, floors are to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are, in general, to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.4.3 The overall depth of transverse floors at the centreline, d_f, is not to be taken as less than:

when $B < 10$ m $d_f = 40\,(B + 0{,}85D)$ mm
when $B \geq 10$ m $d_f = 40\,(1{,}5B + 0{,}85D) - 200$ mm

where
B is as defined in 1.5.1.

5.4.4 The web thickness, t_w, for transverse floors of 'top-hat' type section is to be not less than that required by 1.16 or as determined as follows, whichever is the greater:

$$t_w = \sqrt{k_A}\left(\frac{4{,}33 d_f}{1000} + 2{,}75\right)\left(\frac{s}{1000} + 0{,}5\right) \text{ mm}$$

where
d_f is as defined in 5.4.3.
k_A and s are defined in 1.5.1
In no case is t_w to be taken less than 5,0 mm.

5.4.5 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by 5.4.4.

5.4.6 If side frames are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.4.7 The face area of floors, A_f, is not to be taken as less than:

$$A_f = 0{,}82 L_R \, k_A \text{ cm}^2$$

where
k_A and L_R are as defined in 1.5.1.

5.4.8 The thickness of the face reinforcement, t_f, is to be not less than the web thickness.

5.4.9 In addition, the requirements of 4.8 for bottom transverse web frames are to be complied with.

5.4.10 Floors are generally to be continuous from side to side.

5.4.11 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required mechanical properties of the section.

5.4.12 The floors in the aft peak are to extend over and provide efficient support to the stern tube where applicable.

5.4.13 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3 or 7.4 respectively.

5.5 Floors in machinery spaces

5.5.1 Floors within machinery spaces are to comply with the requirements of 5.4.

5.5.2 The depth and mechanical properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.4.3. The web thickness and face reinforcement weight of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength.

5.6 Machinery seating

5.6.1 The general requirements for machinery seating are given in Pt 3, Ch 2,6.9.

5.6.2 Main and auxiliary engines are to be effectively secured to the hull structure by seatings of adequate scantlings to resist the gravitational thrust, torque and vibration forces which may be imposed upon them.

5.6.3 The longitudinal girders forming the engine seating are to extend as far forward and aft as is practicable and are to be adequately supported by transverse floors or brackets.

5.6.4 Where stiffening is of plate construction, engine holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders. When this cannot be achieved, bracket floors are to be fitted.

5.6.5 Machinery seatings are to be attached by means of primary bonding angles in accordance with 1.18.

5.7 Drainage arrangements

5.7.1 Suitable arrangements are to be made to provide free passage of air from all parts of the tanks to the air pipes, *see also* Pt 9, Ch 1,5.

5.7.2 Sufficient limber holes are to be positioned in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

5.7.3 Particular attention is to be given to the positioning of limbers to ensure adequate drainage and to avoid stress concentrations. *See* LR's *Guidance Notes for Calculation Procedures for Composite Construction*.

5.7.4 Openings in the webs of stiffening sections, baffle plates, etc., are, in general, to be formed by moulded-in preforms under top hat type stiffening. Edges of openings in plate laminates are to be suitably sealed in accordance with 1.29.

5.8 Rudder horns

5.8.1 The scantlings of the rudder horn will be specially considered and in the case of high aspect ratio or novel designs direct calculations will be required to be submitted in accordance with Pt 3, Ch 1,2.

5.9 Sternframes

5.9.1 Where it is proposed to mould a composite sternframe, the scantlings and arrangements will be specially considered on the basis of direct calculations and loadings submitted by the Builders and designers.

5.10 Skeg construction

5.10.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this, *see also* 3.9.

5.10.2 The scantlings of skegs and the internal diaphragms at bulkheads and web frames are to be sufficient to withstand any docking forces to which they may be subjected.

5.11 Forefoot and stem

5.11.1 For craft of composite sandwich construction the forefoot region is to be so designed that in the event of local impact (*see also* 2.8) with floating debris, the resultant damage will be limited. This may be achieved by:
(a) Arranging the individual plies of the laminate such that any delamination will be directed to the outer surface of the laminate, *see* Fig. 3.5.1.
(b) The addition of a 'sacrificial nose', *see* Fig. 3.5.2.
(c) By the addition of suitable sheathing, in accordance with 2.9.
(d) For vessels where the operating high speed waterline results in the exposure of the forefoot region, the laminate sequence in the keel area will be specially considered.

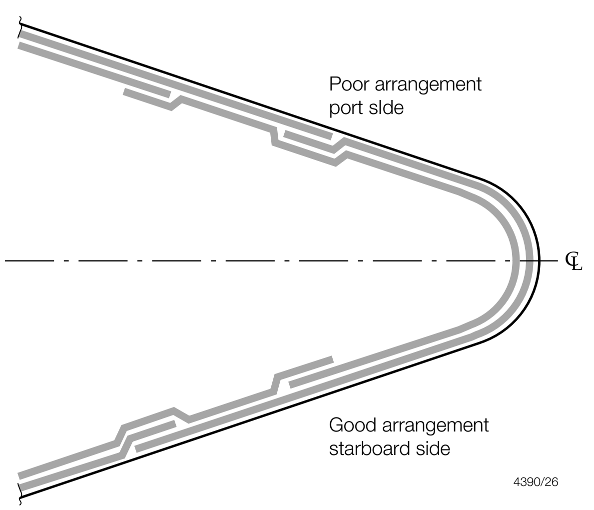


Fig. 3.5.1
Arrangement of laminate in way of forefoot and stem

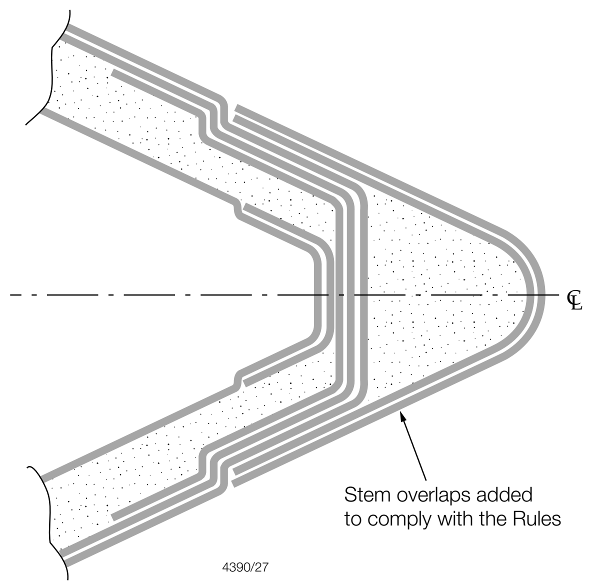


Fig. 3.5.2 'Sacrificial nose'

5.12 Transom knee

5.12.1 Centre and side girders are to be bracketed to the transom framing members by means of substantial knees. The face flat area of the girders may be gradually reduced to that of the transom stiffening member in accordance with Fig. 3.5.3.

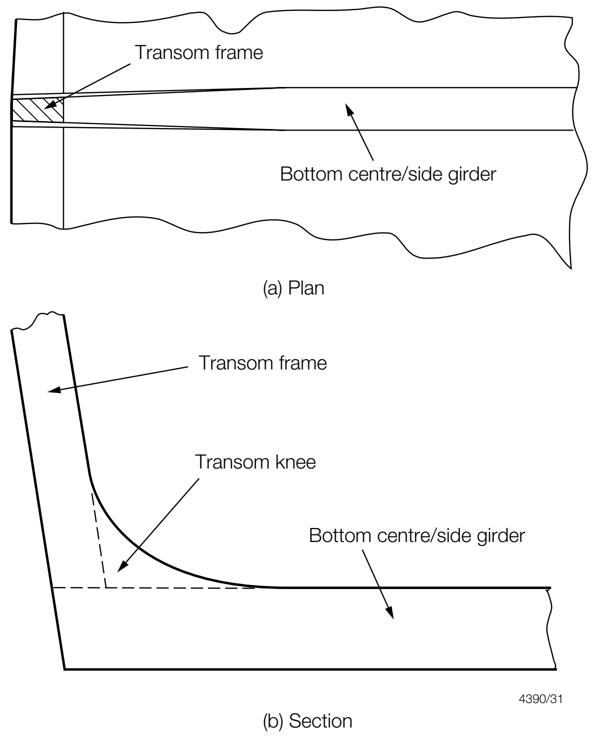


Fig. 3.5.3 Transom knee

5.12.2 Hard spots are to be avoided in way of the end connection, and care taken to ensure that the stiffening member to which the transom knee is bracketed can satisfactorily carry the transmitted bending moment.

■ *Section 6* Double bottom structure

6.1 General

6.1.1 The requirements given in this Section provide for double bottom construction of mono-hull craft in association with either transverse or longitudinal framing.

6.1.2 Where required in accordance with Pt 3, Ch 2,6, double bottoms are generally to extend from the collision bulkhead to the after peak bulkhead, as far as this is practicable taking into account the design and proper working of the craft. In addition, the inner bottom is to be continued to the craft's side in such a manner as to protect the bottom to the turn of bilge or chine.

6.1.3 The double bottom structure in way of girders and duct keels is to be sufficient to withstand the forces imposed by dry-docking the craft.

6.1.4 The centreline girder and side girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

6.2 Keel

6.2.1 The breadth and thickness of plate keels are to comply with the requirements of 3.2.

6.3 Centreline girder

6.3.1 A centreline girder is to be fitted throughout the length of the craft. The web thickness, t_w, of a centreline girder of 'top-hat' type section is to be not less than as required by 1.16 or as determined as follows, whichever is the greater and in no case is t_w to be taken less than 5 mm:

$$t_w = \sqrt{k_A}\left(\frac{L_R}{8} + 3{,}64\right) \geq 5 \text{ mm}$$

where

k_A and L_R are as defined in 1.5.1.

6.3.2 The web thickness of a centreline girder of single plate laminate construction is to be two times the thickness as required by 6.3.1.

6.3.3 The overall depth of the centre girder, d_{DB}, is not to be taken as less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.5 for bottom longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the breadth of the floor at the upper edge does not exceed 6,0 m, side girders are not required.

6.4.2 Where the breadth of the floor at the upper edge exceeds 6,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders, where fitted, are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.3 Under the main engine, girders extending from the bottom to the top plate of the engine seating are to be fitted. The height of the girders is not to be less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors are to be fitted.

6.4.4 Side girders are to have a minimum web thickness, t_w, as required by 1.16 but not less than as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\left(0{,}064L_R + 4{,}32\right) \text{ mm}$$

where

k_A and L_R are as defined in 1.5.1.

6.4.5 The face area and face thickness of side girders are to comply with the requirements for plate floors as defined in 5.4.7 and 5.4.8 respectively.

6.4.6 Additionally, the requirements of 4.5 for bottom longitudinal primary stiffeners are to be complied with.

6.5 Bracket floors

6.5.1 Between plate floors, the shell inner bottom plating is to be supported by bracket floors. The brackets are to have the same thickness as plate floors and, where they are of single skin laminate construction, are to be stiffened on the unsupported edge.

6.5.2 In longitudinally framed craft, the brackets are to extend from the centre or side girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket to be taken less than 3/4 of the depth of centre girder. Brackets are to be fitted at every web frame at the margin plate, and those at the centre girder are to be spaced not more than 1,0 m apart.

6.5.3 In transversely framed craft, the breadth of the brackets attaching the bottom and inner bottom frames to the centre girder and margin plate is to be not less than 3/4 of the depth of the centre girder.

6.6 Plate floors

6.6.1 Plate floors may be of single skin, sandwich skin or ‘top-hat’ type construction.

6.6.2 The web thickness, t_w, for non-watertight plate floors of ‘top-hat’ type section is to be not less than as required by 1.16 or as determined as follows, whichever is the greater and in no case is t_w to be taken less than 5,0 mm.

$$t_w = \sqrt{k_A}\left(0{,}064L_R + 4{,}32\right) \text{ mm}$$

where

k_A and L_R are as defined in 1.5.1.

6.6.3 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by 6.6.2.

6.6.4 The thickness of the plate laminates which form the skins for plate floors of sandwich skin construction are not to be taken as less than 2 mm.

6.6.5 Additionally, the requirements of 4.8 for bottom transverse web frames are to be complied with.

6.6.6 Plate floors are generally to be continuous between the centre girder and the margin plate.

6.7 Watertight floors

6.7.1 The scantlings of watertight floors are to comply with the requirements for plate floors as detailed in 6.6.

6.7.2 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3 or 7.4 respectively.

6.8 Tankside brackets

6.8.1 The scantlings of tankside brackets are to comply with the requirements for plate floors as detailed in 6.6.

6.9 Inner bottom laminate

6.9.1 Inner bottom laminates forming boundaries of tank spaces, are also to comply with the requirements for water-tight bulkheads or deep tanks as detailed in 7.3 or 7.4 respectively and, where forming vehicle, passenger or other decks the requirements of Section 8 are to be complied with.

6.9.2 The bending moment assumed to be carried by the inner bottom plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 6.9.3 and 6.9.5 respectively.

6.9.3 An estimate of the thickness of the **inner bottom single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR’s *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

6.9.4 In no case is the minimum thickness of single skin plating to be taken as less than 5 mm.

6.9.5 An estimate of the stiffness EI, the thickness of single skin plating for **outer and inner skins of the bottom sandwich panel** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

6.9.6 In no case are the minimum thicknesses of laminate which form the skins of a sandwich laminate to be taken as less than 4,5 mm and 3,5 mm for the outer and inner skins respectively.

6.9.7 Special consideration may be given to laminate thicknesses lesser than that required by 6.9.4 and 6.9.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is to be demonstrated as required by 2.8.2.

6.10 Inner bottom longitudinals

6.10.1 The inner bottom longitudinals are to be supported by inner bottom transverse web frames, floors, bulkheads, or other primary structures, generally spaced not more than 2 m apart.

6.10.2 Inner bottom longitudinals are to be continuous through the supporting structures.

6.10.3 Where it is impracticable to comply with the requirements of 6.10.2, or where it is desired to terminate the inner bottom longitudinals in way of bulkheads or integral tank boundaries, the longitudinals are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

6.10.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b).

6.10.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

6.11 Inner bottom transverse web framing

6.11.1 Inner bottom transverse web frames are defined as primary stiffening members which support inner bottom longitudinals. They are to be continuous and substantially bracketed at their end connections to bottom web frames, bottom floors and tankside brackets.

6.11.2 Where it is impracticable to comply with the requirements of 6.11.1, or where it is desired to terminate the inner bottom transverse web frames in way of centre or side girders, bulkheads or integral tank boundaries, etc., all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be ‘soft toed’ and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

6.11.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

6.11.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

6.12 Margin plates

6.12.1 A margin plate, if fitted, is to have a thickness as required for the inner bottom plating.

6.13 Wells

6.13.1 Small wells constructed in the double bottom are not to extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted at the after end of the shaft tunnel of the craft. Other well arrangements (e.g. for lubricating oil under main engines) may be considered provided they give protection equivalent to that afforded by the double bottom.

6.14 Transmission of pillar loads

6.14.1 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided, and where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

6.15 Drainage arrangements

6.15.1 Suitable arrangements are to be made to provide free passage of air and water from all parts of the tanks to the air pipes and pump suctions.

6.15.2 Particular attention is to be given to the positioning of limbers to ensure adequate drainage and to avoid stress concentrations, *see also* 5.7.

6.15.3 Openings in the webs of stiffening sections, baffle plates, etc., are to be suitably sealed in accordance with 4.16.

6.16 Manholes

6.16.1 Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to and ventilation of all parts of the double bottom. The size of the manhole openings in plate laminates is not, in general, to exceed 50 per cent of the double bottom depth unless edge reinforcement is provided. Holes are, in general, not to be cut in the centre girder, except in tanks at the forward and after ends of the craft, and elsewhere where tank widths are reduced unless additional stiffening and/or compensation is fitted to maintain the structural integrity.

6.17 Pressure testing

6.17.1 Double bottoms are to be tested upon completion with a head of water representing the maximum internal pressure which could be experienced in service, but not less than a head of water equivalent to the level of the upper deck.

■ *Section 7* Bulkheads and deep tanks

7.1 General

7.1.1 The requirements of this Section apply to craft with bulkheads of either sandwich or single skin composite construction.

7.1.2 Watertight and collision bulkheads are to be fitted in accordance with the requirements of Pt 3, Ch 2,4.

7.1.3 FRP composite bulkheads and plywood bulkheads are, where practicable, to be suitably attached to receiving frames, *see also* LR's *Guidance Notes for Structural Details*. The bulkheads are to be attached using double angles or equivalent, *see* 1.18. Proposals to fit bulkheads and tank boundaries on receiving strips in lieu of frames, will be individually considered.

7.1.4 Where bulkheads are of steel or aluminium construction, their scantlings and arrangements are to be in accordance with Pt 6, Ch 3 or Pt 7, Ch 3 respectively. The method of attachment to the framing will be specially considered.

7.1.5 For bulkheads in way of partially filled holds or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations which are to be submitted with the plans.

7.1.6 In deep tanks which extend from side to side a centreline bulkhead is generally to be fitted. The bulkhead may be intact or perforated as desired. If intact the scantlings are to comply with the requirements of 7.4 and 7.11 for tank boundary bulkheads. If perforated, they are to comply with the requirements of 7.11 for washplates.

7.1.7 The scantlings of non-watertight or partial bulkheads are, in general, to be as required by 7.3 for watertight bulkheads. Non-watertight or partial bulkheads supporting hull framing are to have scantlings equivalent to frames or web frames, in the same position, as appropriate.

7.2 Symbols and definitions

7.2.1 The symbols and definitions for use within this Section are as given in 1.5.1.

7.3 Watertight bulkheads

7.3.1 Composite watertight bulkheads may be of sandwich construction, with or without stiffeners, or of single skin construction with closely spaced vertical or horizontal stiffeners. Where steel or aluminium alloy bulkheads are fitted, their scantlings and arrangements are to be in accordance with Pt 6, Ch 3 or Pt 7, Ch 3 respectively. Sandwich timber bulkheads, plywood bulkheads or other forms of bulkhead construction will be considered on the basis of equivalent strength and stiffness. Where bulkheads are of novel design they will be specially considered.

7.3.2 The bending moment assumed to be carried by the watertight bulkhead plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 for both non-displacement or displacement type craft. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 7.3.3 and 7.3.5 respectively.

7.3.3 An estimate of the thickness of watertight **bulkhead single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

7.3.4 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

7.3.5 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **bulkhead sandwich panel** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

7.3.6 In no case is the minimum thickness of laminate which forms the skin of a sandwich laminate to be taken as less than 2 mm.

7.3.7 Special consideration may be given to laminate thicknesses lesser than that required by 7.3.4 and 7.3.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

7.3.8 The Rule requirements for bending moment, shear force, shear stress and deflection for the bulkhead stiffeners are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 for both non-displacement or displacement type craft, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the appropriate load model.

7.3.9 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

7.3.10 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as indicated in 1.7.

7.3.11 Bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.3.12 Bulkheads in engine rooms that may be exposed to fuel oils are to be suitably protected against damage by fuel oil and by fire, *see* 7.15.

7.4 Deep tanks

7.4.1 Composite integral/deep tank bulkheads may be of sandwich construction with or without stiffeners, or of single skin with closely spaced vertical or horizontal stiffeners. Where steel or aluminium alloy integral/deep tank bulkheads are fitted, their scantlings and arrangements are to be in accordance with Pt 6, Ch 3 or Pt 7, Ch 3 respectively. Other forms of bulkhead construction will be considered on the basis of equivalent strength and stiffness. Where bulkheads are of novel design they will be specially considered.

7.4.2 The bending moment, M_b or M_c, as appropriate, assumed to be carried by the integral/deep tank bulkhead plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 for both non-displacement or displacement type craft. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 7.4.3 and 7.4.5 respectively.

7.4.3 An estimate of the thickness of **integral/deep tank bulkhead single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

7.4.4 In no case is the minimum thickness of single skin plating to be taken as less than 4,5 mm.

7.4.5 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of **integral/deep tank bulkhead sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

7.4.6 In no case is the minimum thickness of laminate which forms the skins of a sandwich laminate to be taken as less than 4 mm and 3 mm for the fluid barrier and exterior skins respectively, *see also* 2.5.2.

7.4.7 Special consideration may be given to laminate thicknesses less than that required by 7.4.4 and 7.4.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

7.4.8 The Rule requirements for bending moment, shear force, shear stress and deflection for the integral/deep tank stiffeners are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 for both non-displacement or displacement type craft, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

7.4.9 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

7.4.10 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as indicated in 1.7.

7.4.11 Integral/deep tank bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.4.12 Integral/deep tank bulkheads in engine rooms that may be subjected to fuel oils are to be suitably protected against damage by fuel oil and by fire, *see* 7.15.

7.5 Double bottom tanks

7.5.1 The scantlings of double bottom tanks are to meet the structural requirements for deep tanks in accordance with 7.4.

7.5.2 Where the crown of a double bottom tank forms a vehicle, passenger or other deck, the requirements of Section 8 are also to be complied with.

7.6 Collision bulkheads

7.6.1 The scantlings of composite collision bulkheads are to meet the requirements of 7.3 but with allowable tensile, compressive and shear stress limits for collision bulkheads as indicated in Table 7.3.1 in Chapter 7.

7.6.2 If the collision bulkhead forms the boundary of a deep tank or cofferdam the requirements of 7.4 are to be complied with.

7.7 Gastight bulkheads

7.7.1 Where gastight bulkheads are fitted, in accordance with Pt 3, Ch 2,4, their scantlings are to be as required for watertight bulkheads.

7.7.2 Gastight bulkheads are to be fitted to protect accommodation spaces from gases and vapour fumes from machinery, exhaust and fuel systems.

7.8 Plywood bulkheads

7.8.1 Plywood used for bulkheads is to be high quality marine plywood, and is to be in accordance with the requirements of Ch 2,2.17.

7.8.2 The structural requirements of plywood watertight bulkheads are to be as required by 7.1.

7.9 Non-watertight or partial bulkheads

7.9.1 Where a bulkhead is structural but non-watertight, the scantlings are, in general, to be as required for watertight bulkheads or equivalent in strength to web frames in the same position. Partial bulkheads that are non-structural are outside the scope of LR classification.

7.10 Stiffeners passing through bulkheads

7.10.1 Primary longitudinal stiffening members are to be continuous through transverse bulkheads.

7.10.2 Where a stiffener passes through a watertight bulkhead the bonding of the stiffener and compensation in way is to be not less than the laminate weight of the bulkhead.

7.10.3 Where structural members pass through the boundaries of watertight bulkheads or integral/deep tanks, and leakage into the adjacent space could be hazardous or undesirable, suitable cofferdams are to be built into the cores of top-hat stiffeners on each side of the boundary. The minimum thickness of such cofferdams is 4,5 mm.

7.10.4 Pipe or cable runs through watertight bulkheads are to be fitted with suitable watertight glands.

7.11 Wash plates

7.11.1 Tanks are to be subdivided as necessary by internal baffles or wash plates and the minimum thickness of the laminate for any internal structure is not, in general, to be less than 4,5 mm at a fibre content of 0,5 or equivalent thickness. Baffles or wash plates which support hull framing are to have scantlings equivalent to web frames in the same position.

7.11.2 Wash plates and wash bulkheads are, in general, to have an area of perforation not less than 10 per cent of the total area of the bulkhead. The perforations are to be so arranged that the efficiency of the bulkhead as a support is not impaired.

7.11.3 The plate thickness is to be not less than the structural element from which the wash bulkhead is formed.

7.12 Cofferdams

7.12.1 A cofferdam is to be fitted between fresh water and oil fuel or sanitary tanks. The scantlings of cofferdams are to comply with the requirements for deep tank bulkheads given in 7.4.

7.13 Coatings

7.13.1 Fuel tanks are to incorporate a resin rich surface or be coated with an oil retardant resin on the internal exposed surfaces. Potable fresh water tanks are similarly to be coated with a suitable non-tainting resin.

7.14 Air pipes

7.14.1 Air pipes sufficient in number and area are to be fitted to each tank in accordance with Pt 15, Ch 2,11.

7.15 Fire protection

7.15.1 Fire protection requirements as given in Part 17 are to be complied with.

7.16 Access

7.16.1 All compartments within the craft are to be accessible in order to facilitate proper maintenance and future structural surveys. Linings on craft-sides, deck-heads and bulkheads etc., must be capable of being removed. Similarly, sufficient space must be available below lower decks/soles to provide proper access to the bottom structure; an adequate number of manholes, removable panels, etc., are to be provided for this purpose.

7.16.2 Doors fitted through watertight bulkheads are to be of equivalent construction to the bulkhead in which they are fitted, permanently attached, capable of being closed watertight from both sides of the bulkhead and are to be tested watertight.

7.16.3 Doors or hatches are not to be fitted in collision bulkheads, except in craft of less than 21 m Rule length, L_R, or where it would be impracticable to arrange access to the forepeak other than through the collision bulkhead. Where fitted, such doors or hatches are to be watertight, as small as practicable and are to open into the forepeak compartment. Consideration will be given to operation from one side only. Doors or hatches in collision bulkheads are to be kept closed at all times while the craft is at sea.

7.16.4 Particular attention is to be given to the design and workmanship of adequate access manholes in tanks.

7.16.5 Where a manhole is fitted in a tank, the exposed edges of all openings cut in sandwich panels are to be suitably sealed. In general a high density foam core (or equivalent material) is to be used around the perimeter of such openings. Exposed edges in way of cut-outs in sandwich panels are to be overlaminated with a weight of laminate not less than that required for the skin of the sandwich panel exposed to the fluid or 4,5 mm in thickness whichever is the greater, *see* 2.3.1.

7.16.6 Manhole covers are to be attached using bolts/studs spaced at not greater than six diameters. The cover is to be fitted on a suitable seal. Where studs or bolts used to attach the cover plate to the manhole pass through the laminate, they are to be suitably secured, sealed and over-laminated.

7.17 Testing

7.17.1 Integral/deep tanks are to be tested by air pressure or by a head of water. If tested by water, the head is to be either to 1,8 m above the crown of the tank or to the top of the air or overflow pipe, whichever is the greater. When tested by air, the pressure is not to exceed 0,014 N/mm^2. The head to which the tank will be subjected in service is to be indicated on the plans submitted.

■ *Section 8* Deck structures

8.1 General

8.1.1 The deck structure may be of either single skin or sandwich construction and is to be supported by transverse beams with fore and aft girders or by longitudinals with deep transverse beams.

8.1.2 Beams are to be fitted at each frame position and be bracketed to the side frames. Strong beams and deep transverse beams are to align with and be effectively connected to the side web frames. They are also to be fitted at the ends of large openings in the deck.

8.1.3 The ends of beams, longitudinals, girders and transverses are to be effectively built into the adjacent structure, or equivalent arrangements provided.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Deck structures subject to concentrated loads, such as pillars out of line, are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, the stiffener is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

8.1.7 Deck structures are to comply with the minimum thickness requirements of Section 2.

8.1.8 Tripping brackets are to be fitted on deep webs.

8.2 Symbols and definitions

8.2.1 The symbols defined in 1.5.1 apply, unless otherwise specified.

8.3 Strength/weather deck laminate

8.3.1 The bending moment assumed to be carried by the strength/weather deck plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 8.3.2 and 8.3.4 respectively.

8.3.2 An estimate of the thickness of **strength/weather deck single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.3.3 In no case is the minimum thickness of single skin plating to be taken as less than 4 mm.

8.3.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **strength/weather deck sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.3.5 In no case are the minimum thicknesses of reinforcements which form the skins of a sandwich laminate to be taken as less than 3 mm and 2 mm for the outer and inner skins respectively.

8.3.6 Special consideration may be given to laminate thicknesses lesser than that required by 8.3.3 and 8.3.5, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

8.3.7 The scantlings of watertight cockpits are to be of equivalent strength to those for the strength/weather deck, *see also* Part 4.

8.3.8 It is recommended that working areas of the weather deck have an anti-slip surface.

8.3.9 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* 2.9.

8.4 Lower deck/inside deckhouse deck laminate

8.4.1 The bending moment assumed to be carried by the lower deck/inside deckhouse deck plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 8.4.2 and 8.4.4 respectively.

8.4.2 An estimate of the thickness of the **lower deck/ inside deckhouse deck single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.4.3 In no case is the minimum thickness of single skin plating to be taken as less than 3 mm.

8.4.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **lower deck/inside deckhouse deck sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.4.5 In no case is the minimum thickness of laminate which forms the skins of a sandwich laminate to be taken as less than 2 mm.

8.4.6 Special consideration may be given to laminate thicknesses lesser than that required by 8.4.3 and 8.4.5, provided that all of the structural strength requirements of the Rules are complied with.

8.5 Accommodation deck laminate

8.5.1 Accommodation decks are, in general, to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with 8.4.

8.5.2 Sandwich timber, plywood or other forms of deck construction will be considered on the basis of equivalent strength and stiffness.

8.6 Cargo deck laminate

8.6.1 The bending moment assumed to be carried by the cargo deck plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 8.6.2 and 8.6.4 respectively.

8.6.2 An estimate of the thickness of the **cargo deck single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.6.3 In no case is the minimum thickness of single skin plating to be taken as less than 4 mm.

8.6.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **cargo deck sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.6.5 In no case is the minimum thickness of laminate which forms the skins of a sandwich laminate to be taken as less than 3 mm and 2 mm for the outer and inner skins respectively.

8.6.6 Special consideration may be given to laminate thicknesses lesser than that required by 8.6.3 and 8.6.5, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

8.7 Decks forming crown of tanks

8.7.1 Decks forming the crowns of tanks are to comply with the requirements for the appropriate deck and, are to be additionally examined for compliance with the requirements for deep tanks given in 7.4.

8.8 Strength/weather deck stiffening

8.8.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **strength/weather deck primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

8.8.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **strength/weather deck secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.8.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

8.8.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

8.9 Lower deck/inside deckhouse stiffening

8.9.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the lower deck/inside deckhouse stiffeners are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the appropriate load model. Primary members are assumed to be load model (a), secondary members are, in general, assumed to load model (b), however special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.9.2 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

8.9.3 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

8.10 Accommodation deck stiffening

8.10.1 Accommodation decks are, in general, to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with 8.9.

8.11 Cargo decks

8.11.1 The Rule requirements for bending moment, shear force, shear stress and deflection for cargo deck stiffeners are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the appropriate load model. Primary members are assumed to be load model (a), secondary members are, in general, assumed to be load model (b), however special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided. Additionally where the cargo comprises wheeled vehicles the requirements of Ch 5,3 are to be complied with.

8.11.2 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

8.11.3 The geometric properties of stiffeners sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

8.12 Deck openings

8.12.1 All openings are to be supported by an adequate framing system, pillars or cantilevers. When cantilevers are used, stiffening requirements may be derived from direct calculations.

8.12.2 Where stiffening members are stopped in way of an opening, they are to be attached to carlings, girders, transverses or coamings.

8.12.3 The corners of large hatchways in the strength/weather deck within 0,5L amidships are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.12.4 Where elliptical corners are arranged, the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than two to one, nor greater than 2,5 to 1, and the minimum half-length of the major axis is to be defined by l_1 in Fig. 3.8.1. Where parabolic corners are arranged, the dimensions are also to be as shown in Fig. 3.8.1.

8.12.5 Where the corners are parabolic or elliptical, increased thickness of laminate will, in general, not be required.

8.12.6 For other shapes of corner, local reinforcement of the size and extent shown in Fig. 3.8.2 will, in general, be required. The required weight of reinforcement is to be not less than 25 per cent greater than the adjacent deck laminate.

8.12.7 For lower decks the corners of large openings are to be rounded, with a radius generally not less than 1/24 of the breadth of the opening.

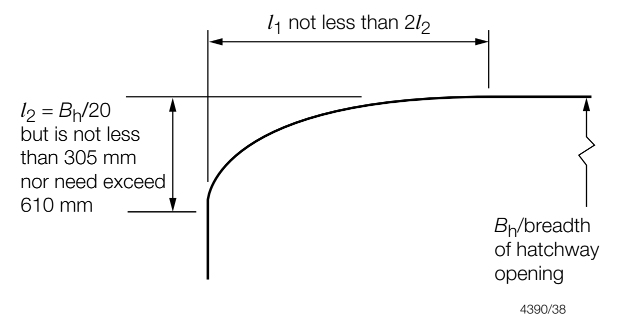


Fig. 3.8.1 Hatch opening geometry

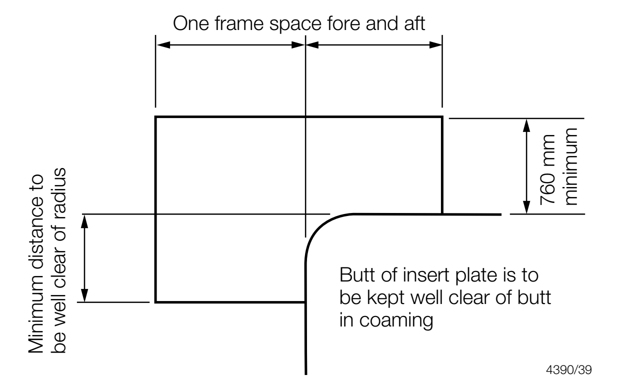


Fig. 3.8.2
Local reinforcement in way of hatch opening

8.12.8 Local reinforcement will be required at lower decks in way of rapid change in hull form to compensate for loss of deck cross-sectional area. Otherwise, local reinforcement will not normally be required.

8.12.9 Adequate transverse strength is to be provided in the deck area between large hatch openings subjected to transverse and buckling loads.

8.12.10 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

8.13 Sheathing

8.13.1 The requirements for deck sheathing are given in 2.9.

8.14 Novel features

8.14.1 Novel features will be specially considered in accordance with 2.7.

8.14.2 Where large or novel hatch openings are proposed, detailed calculations are to be submitted to demonstrate that the scantlings and arrangements in way of the openings are adequate to maintain continuity of structural strength.

■ *Section 9* Superstructures, deckhouses and bulwarks

9.1 General

9.1.1 Superstructures, deckhouses and bulwarks may be of single skin or sandwich construction or a combination of both.

9.1.2 Where practicable, superstructures and deckhouses are to be designed with well cambered decks and well radiused corners to build rigidity into the structure.

9.1.3 The laminate and supporting structure are to be suitably reinforced in way of stressed corners of openings, cranes, masts, derrick posts, machinery, fittings and other heavy or vibrating loads.

9.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

9.1.5 Secondary stiffening members are, in general, to be continuous through supporting structures.

9.1.6 Structures subject to concentrated loads, such as pillars out of line, are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, the stiffener is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

9.1.7 Structures are to comply with the minimum thickness requirements of Section 2.

9.2 Symbols and definitions

9.2.1 The term ‘house’ is used in this Section to include both superstructures and deckhouses.

9.2.2 The symbols for use within this Section are as defined in 1.5.1 unless otherwise specified.

9.3 House side laminates

9.3.1 The bending moment assumed to be carried by the house side plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.3.2 and 9.3.4 respectively.

9.3.2 An estimate of the thickness of **house side single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.3.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.3.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **house side sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.3.5 In no case is the minimum thickness of laminate which forms the skin of a sandwich laminate to be taken as less than 2 mm.

9.4 House front laminates

9.4.1 The bending moment assumed to be carried by the house front plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.4.2 and 9.4.4 respectively.

9.4.2 An estimate of the thickness of **house front single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.4.3 In no case is the minimum thickness of single skin plating to be taken as less than 3,0 mm.

9.4.4 An estimate of the stiffness EI, the thickness of single skin plating for outer and inner skins of the **house front sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.4.5 In no case is the minimum thickness of laminate which forms the skin of a sandwich laminate to be taken as less than 2,5 mm.

9.5 House aft end laminates

9.5.1 The bending moment assumed to be carried by the house aft end plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.5.2 and 9.5.4 respectively.

9.5.2 An estimate of the thickness of **house aft end single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.5.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.5.4 An estimate of the stiffness EI, the thickness of single skin plating for outer and inner skins of the **house aft end sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.5.5 In no case is the minimum thickness of laminate which forms the skin of a sandwich laminate to be taken as less than 2 mm.

9.6 House top laminates

9.6.1 The bending moment assumed to be carried by the house top plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.6.3 and 9.6.5 respectively.

9.6.2 An estimate of the thickness of **house top single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.6.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.6.4 An estimate of the stiffness EI, the thickness of single skin plating for outer and inner skins of the **house top sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.6.5 In no case is the minimum thickness of laminate which forms the skin of a sandwich laminate to be taken as less than 2 mm.

9.7 Coachroof laminates

9.7.1 The bending moment assumed to be carried by the coachroof plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.7.2 and 9.7.4 respectively.

9.7.2 An estimate of the thickness of **coachroof single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.7.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.7.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **coachroof sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.7.5 In no case is the minimum thickness of laminate which forms the skin of a sandwich laminate to be taken as less than 2 mm.

9.8 Machinery casing laminates

9.8.1 The bending moment assumed to be carried by the machinery casing plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.8.2 and 9.8.4 respectively.

9.8.2 An estimate of the thickness of the **machinery casing single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits are indicated in Table 7.3.1 in Chapter 7 for house side plating.

9.8.3 In no case is the minimum thickness of single skin plating to be taken as less than 3,0 mm.

9.8.4 An estimate of the stiffness EI, the thickness of single skin plating for outer and inner skins of the **machinery casing sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.8.5 In no case is the minimum thickness of laminate which forms the skin of a sandwich laminate to be taken as less than 2,5 mm.

9.9 Forecastle requirements

9.9.1 The side laminate may be a continuation of the hull laminate, an integral part of the deck moulding or connected as a separate assembly. The laminate is to be the same weight as the side hull laminate at the deck edge position, and is to be increased along the connection, if fitted, to the top edge of the hull. Suitable scarfing arrangements are to be made to ensure the continuity of the effect of the sheerstrake at the break and at the upper edge of the forecastle side. The laminate is to be stiffened by sideframes carried up or they may be stopped short of the deck provided the ends are effectively built-in. Deep webs are to be fitted to ensure overall rigidity of the side laminate.

9.10 House side stiffeners

9.10.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house side primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

9.10.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house side secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.10.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.10.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.11 House front stiffeners

9.11.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house front primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

9.11.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house front secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.11.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.11.4 The geometric properties of stiffeners sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.12 House aft end stiffeners

9.12.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house aft end primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

9.12.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house aft end secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.12.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.12.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.13 House top stiffeners

9.13.1 The house top is to be efficiently supported by a system of transverse or longitudinal beams and girders. The span of the beams is generally not to exceed 2,4 m and the beams are to be effectively built into the house upper coamings and girders.

9.13.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house top primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

9.13.3 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house top secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.13.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.13.5 The geometric properties of stiffeners sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.14 Coachroof stiffeners

9.14.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **coachroof primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

9.14.2 The Rule requirements for the bending moment, shear force, shear stress and deflection for the **coachroof secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.14.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.14.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.15 Machinery casing stiffeners

9.15.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **machinery casing primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

9.15.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **machinery casing secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.15.4 Where casing sides act as girders supporting decks over, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular attention is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

9.15.5 Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably reinforced.

9.15.6 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.16 Forecastle stiffeners

9.16.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **forecastle primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (a).

9.16.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **forecastle secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.16.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.16.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.17 Superstructures formed by extending side structure

9.17.1 Superstructure first tier sides formed by extending the hull side structure are to be in accordance with the requirements for house fronts indicated in 9.4 and 9.11 for laminates and stiffeners respectively, but need not be taken as greater than the side structure requirements at the deck edge at the same longitudinal position.

9.18 Fire aspects

9.18.1 Fire detection, protection and extinction requirements are given in Part 17.

9.19 Openings

9.19.1 All openings are to be substantially framed and have well rounded corners. Arrangements are to be made to minimise the effect of discontinuities. Continuous coamings or girders are to be fitted below and above doors and similar openings.

9.19.2 Particular attention is to be paid to the effectiveness of end bulkheads when large openings for doors and windows are fitted, and also to the upper deck stiffening in way.

9.19.3 Special care is to be taken to minimise the size and number of openings in the side bulkheads in the region of the ends of houses within 0,5L_R amidships. Account is to be taken of the high vertical shear loading which may occur in these areas.

9.19.4 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

9.20 Mullions

9.20.1 Window openings are to be suitably framed and mullions will in general be required.

9.20.2 The scantlings of mullions are to be not less than as required for a stiffener in the same position.

9.20.3 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as indicated in 1.7, in no case is the width of effective plating to be taken greater than the distance between adjacent window openings.

9.20.4 Where significant shear forces are to be transmitted by window frames, adequate shear rigidity requires to be verified.

9.21 Global strength

9.21.1 Transverse rigidity is to be maintained throughout the length of the house by means of web frames, bulkheads or partial bulkheads. Particular attention is to be paid when a superimposed tier is wider than its supporting tier and when significant loads are carried on the house top.

9.21.2 Where practicable, web frames are to be arranged in line with bulkheads below.

9.21.3 Internal bulkheads are to be fitted in line with bulkheads or deep primary stiffeners below.

9.22 House/deck connection

9.22.1 Adequate support under the ends of houses is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams.

9.22.2 Special attention is to be given to the connection of the house to the deck in order to provide an adequate load distribution and avoid stress concentrations.

9.22.3 Typical design details of house/deck connections are given in LR's *Guidance Notes for Structural Details*.

9.23 Sheathing

9.23.1 Sheathing arrangements are to comply with 2.9.

9.24 Novel features

9.24.1 Laminate and stiffener requirements may need to be determined by direct calculation where the house is of unusual design, form or proportions, *see also* 2.7.

9.25 Bulwarks

9.25.1 General requirements for bulwarks are given in Pt 3, Ch 4.8.

9.25.2 The bending moment assumed to be carried by the bulwark plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.25.3 and 9.25.5 respectively.

9.25.3 An estimate of the thickness of the **bulwark single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.25.4 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.25.5 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **bulwark sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.25.6 In no case is the minimum thickness of laminate which forms the skin of a sandwich laminate to be taken as less than 2 mm.

9.25.7 The Rule requirements for bending moment, shear force, shear stress and deflection for the **bulwark stays** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 for the load model (d).

9.25.8 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.25.9 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.25.10 Bulwarks should not be cut for gangway or other openings near the breaks of houses.

9.25.11 Attention is to be paid to avoid discontinuity of strength of the bulwark, particularly in way of local increases in stress and changes in height.

9.25.12 **Fishing craft** are to have bulwarks fitted. The bulwark may be formed as a continuation of the hull laminate, an integral part of the deck moulding or connected as a separate assembly. Where the bulwark is considered to be stressed and contributing to the global strength of the craft, the laminate weight of the bulwark is not to be less than the sheer laminate weight. In no case is the bulwark laminate weight to be taken as less than 80 per cent of the shell weight. The bulwark is to be supported by suitable stiffening which may be formed by a continuation of the side frames, or by top hat, or plate laminate stays of the same weight as the bulwark. These frames are not generally to be spaced more than two side frame spacings apart.

9.25.13 In way of gantries, trawl gallows, mooring pipes etc. the laminate in way is to be increased by 50 per cent.

9.25.14 **Pilot craft** are to be fitted with sufficient hand rails adjacent to the exposed areas of the working decks and platforms and in addition these areas should have non skid surfaces.

9.26 Freeing arrangements

9.26.1 The requirements for freeing arrangements are given in Pt 3, Ch 4,9.

9.27 Free flow area

9.27.1 The requirements for free flow area are given in Pt 3, Ch 4,9.3.

9.28 Guard rails

9.28.1 The requirements for guard rails are given in Pt 3, Ch 4,8.4.

■ *Section 10* Pillars and pillar bulkheads

10.1 General

10.1.1 Pillars are to be arranged to transmit loads from decks and superstructures into the bottom structure. Pillars are to be constructed out of materials of adequate compressive strength and modulus, usually steel or aluminium and these are generally to be of solid, tubular or I beam form. A pillar may be a fabricated trunk or partial bulkhead.

10.2 Symbols and definitions

10.2.1 The symbols for use within this Section are as defined in 1.5.1, unless otherwise specified in the appropriate sub-Section.

10.3 Determination of spans

10.3.1 The effective span length of pillar, l_{ep}, is in general the distance between the head and heel of pillar. Where substantial brackets are fitted, the effective length of pillar, l_{ep}, may be reduced by 2/3 of the depth of the brackets at each end.

10.4 Head and heel connection

10.4.1 The structure in way of head and heel connections is to be suitably reinforced. The webs and face reinforcement of such supporting structure are to be locally increased as necessary with due account being taken of both the compression and bending moment in way.

10.4.2 Pillars are to be attached at their heads and heels to plates supported by efficient brackets. Where the attachment is through bolted, suitable inserts or compression tubes are to be incorporated within the deck and hull framing to prevent over-compression and damage to the laminate in way. Alternatively, tapping plates may be incorporated within the face reinforcement of the stiffener. Details of the proposed arrangement are to be indicated on the submitted plans.

10.5 Alignment and arrangement

10.5.1 Pillars are to be fitted on main structural members. They should be fitted below deckhouses, windlasses,winches, capstans and elsewhere where considered necessary.

10.5.2 Wherever possible, deck pillars are to be fitted in the same vertical line as pillars above and below, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

10.5.3 Where pillars support eccentric loads, or are subjected to lateral pressures, they are to be suitably strengthened for the additional bending moment imposed upon them.

10.6 Minimum thickness

10.6.1 The minimum wall thickness of steel or aluminium pillars are to be as required by Pt 6, Ch 3 or Pt 7, Ch 3 respectively.

10.6.2 The minimum wall thickness of FRP pillars will be specially considered.

10.7 Pillar scantlings

10.7.1 The scantlings of steel or aluminium pillars, and pillar bulkheads, are to be as required by Pt 6, Ch 3 and Pt 7, Ch 3 respectively.

10.7.2 The scantlings of FRP pillars/pillar bulkheads are to be in accordance with 10.10.

10.7.3 Where a pillar is of unusual material, the scantlings will be specially considered.

10.8 Pillars in tanks

10.8.1 Pillars are in no circumstances to pass through tanks. Where loads are to be transmitted through the tank, pillars within the tanks are to be carefully aligned with the external pillars.

10.8.2 Pillars within tanks are, in general, to be of solid cross section. Proposals to use hollow section or tubular pillars will be subject to special consideration and the scantlings as determined from the Rules may be required to be increased dependent upon the material to be used, the fluid contained and the arrangement of the pillars. Hollow pillars are to be adequately drained and vented.

10.8.3 Pillars within tanks which may be subjected to tensile stresses due to hydrostatic pressure, are to be designed to provide sufficient connection to withstand the tension load imposed.

10.9 Pillar bulkheads

10.9.1 Where the pillar bulkhead is of steel or aluminium construction the method of attachment to the surrounding structure/framing will be specially considered.

10.9.2 Where a pillar bulkhead supports a concentrated load the structure in way is to be suitably reinforced to distribute the load into the adjacent stiffening.

10.10 Composite pillars and pillar bulkhead scantlings

10.10.1 The load P_p, assumed to be carried by a pillar is to be determined from:

$$P_p = S_{gt}\, b_{gt}\, P_c + P_a \quad \text{kN}$$

where

P_p = design load supported by the pillar, which is to be taken as not less than 5 kN

P_c = basic deck girder design pressure as appropriate, plus any other loadings above the pillar, in kN/m^2

P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over

S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillars, in metres.

10.10.2 The load P_b, assumed to be carried by a pillar bulkhead is to be determined from:

$$P_{pb} = S_{bs}\, b_{pb}\, P_c + P_a \quad \text{kN}$$

where

P_{pb} = design load supported by the stiffener plate combination of the pillar bulkhead, in kN

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

S_{bs} = spacing, or mean spacing of bulkheads or effective transverses/longitudinal stiffeners, in metres

b_{pb} = distance between centres of two adjacent spans of girders or transverses supported by the pillar bulkhead, in metres, and can be taken as the distance between pillar bulkhead stiffeners where the stiffener at the top of the bulkhead effectively distributes the load evenly into the stiffeners.

10.10.3 The slenderness ratio (l_{ep}/r) of a pillar or plate stiffener combination is to be determined from:

$$r = \sqrt{\frac{\Sigma (E_i\, I_i)}{\Sigma (E_i\, A_i)}} \quad \text{cm}$$

where

r = least radius of gyration of pillar cross section, in cm

l_{ep} = effective length of pillar, in cm

E_i, I_i and A_i are as defined in 1.5.1.

10.10.4 The compressive loads P_p or P_{pb}, from 10.10.1 and 10.10.2 for pillars and pillar bulkheads respectively are not to exceed a function of the critical load P_{cr}, determined from 10.10.5:

$$P_p \text{ (or } P_{pb}) < f_p\, P_{cr} \quad \text{kN}$$

where

f_p is a factor dependent upon location and is as indicated in Table 3.10.1.

Table 3.10.1 Pillar location factors

Location	f_p
Supporting weatherdeck	0,50
Supporting vehicle deck	0,25
Supporting passenger deck	0,50
Supporting lower/inner deck	0,75
Supporting coachroof	0,75
Supporting deckhouse top	1,00

10.10.5 The critical compressive load, P_{cr}, for pillars and plate/stiffener combinations with a slenderness ratio (l_e/r) between 75 and 110 may be determined from:

$$P_{cr} = \frac{k\,\pi^2\,\Sigma\,(E_{ci}\,I_i)}{l_{ep}^2} \text{ kN}$$

where

l_{ep} = effective span length of pillar or stiffener plate combination, in metres
E_{ci} = compressive modulus of plate laminate, in N/mm^2
k = end fixity factor
= 1,5 for full fixed/bracketed
= 0,75 for partially fixed
= 0,5 for free ended

Where the proposed slenderness ratio is below 75 the pillar will be specially considered. Slenderness ratios in excess of 110 are not to be contemplated.

10.10.6 The stiffener/plate combination used to determine the scantlings for pillar bulkheads is to be that of a stiffener with an effective width of attached plating carrying a load as determined from 1.7.

10.10.7 The scantlings of wooden pillar bulkheads will be specially considered on the basis of the Rules. Such pillar bulkheads are to be of equivalent strength, stiffness and load carrying capability.

10.11 Detail in way of sandwich structure

10.11.1 The attachment of pillars to sandwich structures should, in general, be through an area of single skin laminate, *see* Ch 2,4.3. Where this is not practicable and the attachment of the pillar has to be by bolting through a sandwich structure then a wood, or other suitable solid insert is to be fitted in the core in way.

10.12 Fire aspects

10.12.1 Pillars are to be suitably protected against fire, where necessary, be self extinguishing or be capable of resisting fire damage. All pillars are to comply with Part 17.

10.13 Novel features

10.13.1 Where pillars are of unusual design or constructed from novel material they will be specially considered in accordance with 2.7.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to multi-hull craft of composite construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 Except as otherwise specified within this Chapter, the scantlings and arrangements of multi-hull craft are to be determined in accordance with the procedures described in, or as required by Chapter 3 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,2.

1.5 Symbols and definitions

1.5.1 Unless otherwise specified the symbols and definitions for use within this Chapter are as defined in Ch 3,1.5.

1.5.2 **Bottom outboard**. For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom outboard shell is defined as the area of the hull between the outboard edge of the keel and the outer bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures, the bottom outboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.3 **Bottom inboard**. For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom inboard shell is defined as the area of the hull between the inboard edge of the keel and the inner bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom inboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.4 **Cross-deck**. The cross-deck is defined as the structure which forms the bridge connection between any two adjacent hulls.

1.5.5 **Haunch**. The haunch is defined as the transition area between the cross-deck and the side inboard shell laminate.

1.5.6 **Side inboard**. The side inboard is defined as the area between the bottom inboard shell and the wet-deck (or lower edge of the haunches, where fitted).

1.5.7 **Side outboard**. The side outboard is defined as the area between bottom outboard shell and the deck at side.

1.5.8 **Wet-deck**. The wet-deck is defined as the area between the upper edges of the side inboard laminate (or upper edges of the haunches, where fitted).

■ *Section 2* Minimum thickness requirements

2.1 General

2.1.1 The minimum thickness requirements are to be in accordance with Ch 3,2.

2.1.2 In addition, where laminates contribute to the global strength of the craft, the thickness is to be not less than that required to satisfy global strength requirements.

Section 3
Shell envelope laminate

3.1 General

3.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for the shell envelope laminate are to be determined in accordance with the procedures described in, or as required by Ch 3,3 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

3.2 Keel plates

3.2.1 The breadth, b_K, and thickness, t_K, of plate keels are not to be taken as less than:

$b_K = 5,0 L_R + 250$ mm

$t_K = \sqrt{k_t}\,(5,0 L_R^{0,45})$ mm

where

L_R = Rule length, in metres, as defined in Pt 3, Ch 2,6.1

k_t is as defined in Ch 3,2.1.

3.2.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell laminate.

3.2.3 The width and thickness of plate keels are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard measured at the forward perpendicular (FP) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by Ch 3,3.3.1 for the stem. Laminate tapers are to comply with Ch 3,2.6.2.

3.2.4 Where the bottom shell is of sandwich construction the keel is to be formed by locally returning to single skin construction for a width as required by 3.2.1. The Rule thickness of keel is to comprise both the inner and outer skins of the adjacent bottom shell sandwich plus additional reinforcement as required. The distribution of reinforcement in way of the plate keel and sandwich bottom structure is to be in accordance with Fig. 4.3.1. *See also* Ch 3,3.2.4.

3.2.5 For large, novel, asymmetric hull form craft, or yachts with externally attached ballast keels, or where it is proposed to incorporate keels of the 'bar' type the scantlings of the keel will be specially considered.

3.3 Bottom outboard

3.3.1 For all craft types, the minimum bottom outboard shell laminate thickness as required by the Rules is to be extended over the region as defined in 1.5.2 for displacement and semi-displacement craft.

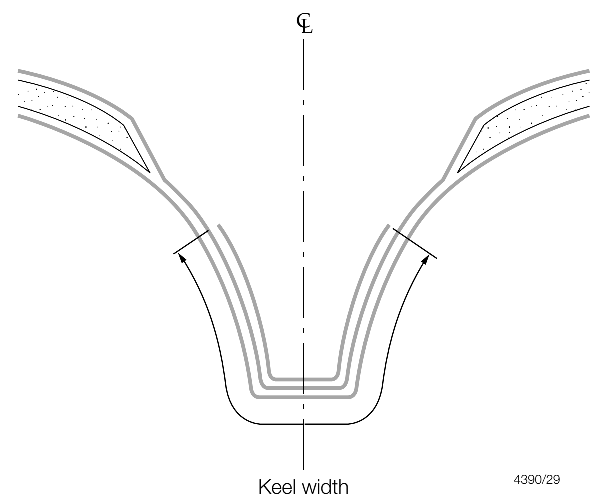


Fig. 4.3.1
Single skin/Sandwich skin intersection detail

3.3.2 The bending moment assumed to be carried by the bottom outboard shell laminate is to be not less than that determined by Ch 3,1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.3.3 and 3.3.5 respectively.

3.3.3 An estimate of the thickness of **bottom outboard single skin laminate** is to be determined from Ch 3,1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.12.3 and Ch 3,1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.3.4 In no case is the minimum thickness of single skin laminate to be taken as less than 5,5 mm.

3.3.5 An estimate of the stiffness EI, the thickness of single skin laminate for outer and inner skins of the **bottom outboard sandwich panel** and the thickness of core material is to be determined from Ch 3,1.13.2 and Ch 3,1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.13.7 and Ch 3,1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.3.6 In no case are the minimum thicknesses of laminate which form the skins of a sandwich laminate to be taken as less than 4,5 mm and 3,5 mm for the outer and inner skins respectively.

3.3.7 Special consideration may be given to laminate thicknesses lesser than those required by 3.3.4 and 3.3.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* Ch 3,2.3.1, and the equivalent impact resistance is demonstrated as required by Ch 3,2.8.2.

3.4 Bottom inboard

3.4.1 The scantlings and arrangements for bottom inboard shell laminate are to be determined in accordance with the procedures described in 3.3 using the bottom inboard shell design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.5 Side outboard

3.5.1 The side outboard shell is as defined in 1.5.7.

3.5.2 For all craft types, the minimum side outboard shell laminate thickness as required by the Rules is to be extended over the region as defined in 3.5.1 for displacement and semi-displacement craft.

3.5.3 The bending moment assumed to be carried by the side outboard shell laminate is to be not less than that determined by Ch 3,1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.5.4 and 3.5.6 respectively.

3.5.4 An estimate of the thickness of **side outboard single skin laminate** is to be determined from Ch 3,1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.12.3 and Ch 3,1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.5.5 In no case is the minimum thickness of single skin laminate to be taken as less than 5 mm.

3.5.6 An estimate of the stiffness EI, the thickness of single skin laminate for outer and inner skins of the **side outboard sandwich panel** and the thickness of core material is to be determined from Ch 3,1.13.2 and Ch 3,1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.13.7 and Ch 3,1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.5.7 In no case are the minimum thicknesses of laminate which form the skins of a sandwich laminate to be taken as less than 4 mm and 3 mm for the outer and inner skins respectively.

3.5.8 Special consideration may be given to laminate thicknesses lesser than those required by 3.5.5 and 3.5.7, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* Ch 3,2.3.1, and the equivalent impact resistance is demonstrated as required by Ch 3,2.8.2.

3.6 Side inboard

3.6.1 The scantlings and arrangements for side inboard shell laminate are to be determined in accordance with the procedures described in 3.3 using the side inboard shell design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate.

3.7 Wet-deck

3.7.1 The wet-deck is as defined in 1.5.8.

3.7.2 The bending moment assumed to be carried by the wet-deck laminate is to be not less than that determined by Ch 3,1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.7.3 and 3.7.5 respectively.

3.7.3 An estimate of the thickness of wet-deck single skin laminate is to be determined from Ch 3,1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.12.3 and Ch 3,1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.7.4 In no case is the minimum thickness of single skin laminate to be taken as less than 5 mm.

3.7.5 An estimate of the EI, the thickness of single skin laminate for outer and inner skins of the wet-deck sandwich panel and the thickness of core material is to be determined from Ch 3,1.13.2 and Ch 3,1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.13.7 and Ch 3,1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.7.6 In no case are the minimum thicknesses of laminate which form the skins of a sandwich laminate to be taken as less than 4 mm and 3 mm for the outer and inner skins respectively.

3.7.7 Special consideration may be given to laminate thicknesses lesser than those required by 3.7.4 and 3.7.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* Ch 3,2.3.1, and the equivalent impact resistance is demonstrated as required by Ch 3,2.8.2.

3.7.8 The wet-deck laminate on the underside of the cross-deck structure may require to be additionally protected, particularly where the air gap is small and there is a high risk of localised impact due to collision with floating debris, ice, etc., in the service area. In such cases the requirements for sheathing, given in Ch 3,2.9, are to be complied with.

3.8 Transom

3.8.1 The scantlings and arrangements of transoms are to be not less than as required for the adjacent bottom inboard or side outboard structure as appropriate.

3.8.2 Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.9 Haunch reinforcement (SWATH)

3.9.1 For craft above 30 m in length, L_R, the stresses in the haunch area are to be derived using a two dimensional fine mesh finite element analysis. The model is to extend horizontally into the box structure and vertically into the strut structure. All discontinuities and cut-outs are to be modelled in order to determine shear stresses at critical locations and stresses for the determination of fatigue strength.

3.9.2 Due consideration is to be given to shear lag when calculating the effective breadth of the attached laminate.

3.10 Lower hull (SWATH)

3.10.1 Where the lower hull structure incorporates ring frames and attached shell laminate fitted between bulkheads or diaphragms, the thickness of the lower hull shell laminate may be derived from an established method for shell analysis or recognised standard for pressure vessels. Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. Copies of direct calculations are to be submitted for consideration.

3.10.2 In general the design load to be used is the pressure load given in Pt 5, Ch 4,3.1. If other loads are considered to be of significance for the scantling determination these are to be taken into account.

3.11 Novel features

3.11.1 Where the Rules do not specifically define the requirements for laminate elements with novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

■ *Section 4* Shell envelope framing

4.1 General

4.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for shell envelope framing are to be determined in accordance with the procedures described in, or as required by Ch 3,4 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

4.1.2 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 Bottom outboard longitudinal stiffeners

4.2.1 The bottom outboard longitudinal stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom outboard longitudinal stiffeners are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is desired to terminate the bottom outboard longitudinal stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.2.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1, or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (b).

4.2.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7 and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.3 Bottom outboard longitudinal primary stiffeners

4.3.1 The bottom outboard longitudinal primary stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.3.2 Bottom outboard longitudinal primary stiffeners are to be continuous through the supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is desired to terminate the bottom outboard longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.3.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

4.3.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.4 Bottom outboard transverse stiffeners

4.4.1 Bottom outboard transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.4.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (b).

4.4.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.5 Bottom outboard transverse frames

4.5.1 Bottom outboard transverse frames are defined as stiffening members which support the bottom shell, they are to be effectively continuous and be bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

4.5.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.6 Bottom outboard transverse web frames

4.6.1 Bottom outboard transverse web frames are defined as primary stiffening members which support bottom shell longitudinals, they are to be continuous and be substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is desired to terminate the bottom inboard transverse web frames in way of bulkheads or integral tank boundaries, etc., all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' (*see* Fig. 3.4.1 in Chapter 3) and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The Rule requirements for the bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

4.6.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.7 Bottom inboard longitudinal stiffeners

4.7.1 The scantlings and arrangements for bottom inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.2 using the bottom inboard longitudinal stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.8 Bottom inboard longitudinal primary stiffeners

4.8.1 The scantlings and arrangements for bottom inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.3 using the bottom inboard longitudinal primary stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.9 Bottom inboard transverse stiffeners

4.9.1 The scantlings and arrangements for bottom inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.4 using the bottom inboard transverse stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.10 Bottom inboard transverse frames

4.10.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.5 using the bottom inboard transverse frames design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.11 Bottom inboard transverse web frames

4.11.1 The scantlings and arrangements for bottom inboard transverse web frames are to be determined in accordance with the procedures described in 4.6 using the bottom inboard transverse web frames design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.12 Side outboard longitudinal stiffeners

4.12.1 The side outboard longitudinal stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.12.2 Side outboard longitudinal stiffeners are to be continuous through the supporting structures.

4.12.3 Where it is impracticable to comply with the requirements of 4.12.2, or where it is desired to terminate the side outboard longitudinal stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.12.4 The Rule requirements for the bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (b).

4.12.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.13 Side outboard longitudinal primary stiffeners

4.13.1 The side outboard longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.13.2 Side outboard longitudinal primary stiffeners are to be continuous through the supporting structures.

4.13.3 Where it is impracticable to comply with the requirements of 4.13.2, or where it is desired to terminate the side outboard longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.13.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

4.13.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.14 Side outboard transverse stiffeners

4.14.1 Side outboard transverse stiffeners are defined as local stiffening members which support the side shell, and which may be continuous or intercostal.

4.14.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (b).

4.14.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.15 Side outboard transverse frames

4.15.1 Side outboard transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.15.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

4.15.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.16 Side outboard transverse web frames

4.16.1 Side outboard transverse web frames are defined as primary stiffening members which support side shell longitudinals, they are to be continuous and be substantially bracketed at their end connections to side web frames and side floors.

4.16.2 Where it is impracticable to comply with the requirements of 4.16.1, or where it is desired to terminate the side outboard transverse web frames in way of bulkheads or integral tank boundaries, etc., all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed', *see* Fig. 3.4.1 in Chapter 3, and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.16.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

4.16.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.17 Side inboard longitudinal stiffeners

4.17.1 The scantlings and arrangements for side inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.12 using the side inboard longitudinal stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.18 Side inboard longitudinal primary stiffeners

4.18.1 The scantlings and arrangements for side inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.8 using the side inboard longitudinal primary stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.19 Side inboard transverse stiffeners

4.19.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.14 using the side inboard transverse stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.20 Side inboard transverse frames

4.20.1 The scantlings and arrangements for side inboard transverse frames are to be determined in accordance with the procedures described in 4.15 using the side inboard transverse frames design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.21 Side inboard transverse web frames

4.21.1 The scantlings and arrangements for side inboard transverse web frames are to be determined in accordance with the procedures described in 4.16 using the side inboard transverse web frames design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.22 Wet-deck longitudinal stiffeners

4.22.1 The wet-deck longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.22.2 Wet-deck longitudinal stiffeners are to be continuous through the supporting structures.

4.22.3 Where it is impracticable to comply with the requirements of 4.22.2, or where it is desired to terminate the wet-deck longitudinal stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.22.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (b).

4.22.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.22.6 In no case are the scantlings and arrangements for the wet-deck longitudinal stiffeners to be taken less than as required for the side inboard longitudinal stiffeners indicated in 4.17.

4.23 Wet-deck longitudinal primary stiffeners

4.23.1 The wet-deck longitudinal primary stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.23.2 Wet-deck longitudinal primary stiffeners are to be continuous through the supporting structures.

4.23.3 Where it is impracticable to comply with the requirements of 4.23.2, or where it is desired to terminate the wet-deck longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.23.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

4.23.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.23.6 In no case are the scantlings and arrangements for the wet-deck longitudinal primary stiffeners to be taken less than as required for the side inboard longitudinal primary stiffeners indicated in 4.18.

4.23.7 Additionally the requirements of Chapter 6, in respect of global strength are to be complied with.

4.24 Wet-deck transverse stiffeners

4.24.1 Wet-deck transverse stiffeners are defined as local stiffening members which support the wet-deck shell, and which may be continuous or intercostal.

4.24.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (b).

4.24.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.24.4 In no case are the scantlings and arrangements for the wet-deck transverse stiffeners to be taken less than as required for the side inboard transverse stiffeners indicated in 4.19.

4.25 Wet-deck transverse frames

4.25.1 Wet-deck transverse frames are defined as stiffening members which support the wet-deck shell, they are to be effectively continuous and be bracketed at their end connections to side frames and side floors as appropriate.

4.25.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

4.25.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.25.4 In no case are the scantlings and arrangements for the wet-deck transverse frames to be taken less than as required for the side inboard transverse frames indicated in 4.20.

4.26 Wet-deck transverse web frames

4.26.1 Wet-deck transverse web frames are defined as primary stiffening members which support wet-deck longitudinals, they are to be continuous and be substantially bracketed at their end connections to side web frames and side floors.

4.26.2 Where it is impracticable to comply with the requirements of 4.26.1, or where it is desired to terminate the wet-deck transverse web frames in way of bulkheads or integral tank boundaries, etc., all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed', *see* Fig. 3.4.1 in Chapter 3, and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.26.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

4.26.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.26.5 In no case are the scantlings and arrangements for the wet-deck transverse web frames to be taken less than as required for the side inboard transverse web frames indicated in 4.21.

4.26.6 Primary transverse web frame members which link the strength deck to the wet-deck structure and which carry the transverse global loading, are additionally to comply with Ch 6,3.4.

4.26.7 Particular care is to be taken to ensure that the continuity of transverse structural strength is maintained. All primary transverse members are to be continuous through the side inboard structure and be integrated into transverse bulkheads or other primary structure within each hull, *see* Fig. 4.4.1. In the case of trimaran type craft the primary transverse members are to be continuous through the centre hull. Additionally the side inboard shell laminate in way of the intersection is to be locally increased in thickness by not less than 50 per cent. Copies of direct calculations are to be submitted for consideration.

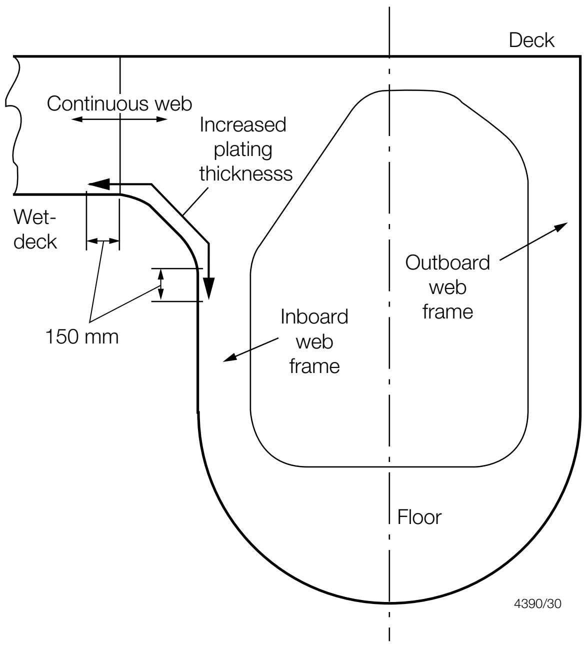


Fig. 4.4.1
End connection detail, wet-deck structure

4.27 Novel features

4.27.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

■ *Section 5*
Single bottom structure and appendages

5.1 General

5.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for single bottom structure and appendages are to be determined in accordance with the procedures described in, or as required by Ch 3,5 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

5.1.2 The minimum thickness requirements detailed in 2.1 are to be complied with as appropriate.

5.2 Keel

5.2.1 The scantlings and arrangements of plate keels are to be in accordance with 3.2. Where it is proposed to incorporate keels of the bar type such arrangements would require to be specially considered.

5.3 Centre girder

5.3.1 Centreline girders are to be fitted throughout the length of each hull and are generally to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders may be formed with intercostal or continuous top hat or plate webs. Where girder webs are intercostal, additional bracketing and local reinforcement are to be provided to maintain the continuity of structural strength. The face reinforcement in all cases is to be continuous.

5.3.3 The web depth of the centre girder in general is to be equal to the depth of the floors at the centreline as specified in 5.5.

5.3.4 The web thickness, t_w, for a centre girder of 'top-hat' type section is to be not less than that required by Ch 3,1.16. or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\left(\sqrt{L_R} + 1{,}37\right) \text{ mm}$$

where

k_A and L_R are as defined in Ch 3,1.5.1.

5.3.5 The web thickness for a centre girder of single plate laminate construction is to be two times the thickness as required by 5.3.4.

5.3.6 The face area of the centre girder, A_f, is to be not less than:

$A_f = 1{,}18 L_R k_A$ cm²

where

$k_A = \dfrac{85}{\sigma_u}$

σ_u = ultimate tensile strength of the face area laminate, in N/mm²

L_R = as defined in Ch 3,1.5.1.

5.3.7 The face area of the centre girder outside $0{,}5L_R$ about midships may be reduced to 80 per cent of the value given in 5.3.6.

5.3.8 The face thickness, t_f, is to be not less than the web thickness of the centre girder.

5.3.9 Additionally, the requirements of 4.8 for bottom longitudinal primary stiffeners are to be complied with.

5.4 Side girder

5.4.1 Where the floor breadth at the upper edge exceeds 4,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders where fitted are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 In the engine room, additional side girders are generally to be fitted in way of the main machinery.

5.4.3 The face area of side girders, A_f, is not to be taken as less than:

$A_f = 0{,}82 L_R k_A$ cm²

where

k_A and L_R are as defined in Ch 3,1.5.1.

5.4.4 The web thickness, t_w, for side girders of 'top-hat' type section is to be not less than as required by Ch 3,1.16. or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$t_w = \sqrt{0{,}66 k_A L_R}$ mm

where

k_A and L_R are as defined in Ch 3,1.5.1.

5.4.5 The web thickness for side girders of single plate laminate construction is to be two times the thickness as required by 5.4.4.

5.4.6 Additionally, the requirements of 4.8 for bottom longitudinal primary stiffeners are to be complied with.

5.4.7 Watertight side girders, or side girders forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in Ch 3,7.3. and Ch 3,7.4 respectively.

5.5 Floors

5.5.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.5.2 In longitudinally framed craft, floors are to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.5.3 The overall depth of transverse floors at the centreline, d_W, is not to be taken as less than:

$d_W = 6{,}2 L_R + 50$ mm

5.5.4 The web thickness, t_w, for transverse floors of 'top-hat' type section is to be not less than as required by Ch 3,1.16. or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\left(\frac{4{,}33 d_W}{1000} + 2{,}75\right)\left(\frac{s}{1000} + 0{,}5\right) \text{ mm}$$

where

d_W = as defined in 5.5.3

k_A and s are as defined in 5.3.6.

5.5.5 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by 5.5.4.

5.5.6 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.7 The face area of floors, A_f, is not to be taken as less than:

$A_f = 0{,}82 L_R k_A$ cm²

where

k_A and L_R are as defined in Ch 3,1.5.1.

5.5.8 The thickness of the face laminate, t_f, is to be not less than the web thickness.

5.5.9 In addition, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

5.5.10 Floors are generally to be continuous from side to side.

5.5.11 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required mechanical properties of the section.

5.5.12 The floors in the aft peak are to extend over and provide efficient support to the stern tube(s) where applicable.

5.5.13 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in Ch 3,7.3 or Ch 3,7.4 respectively.

5.6 Floors in machinery space

5.6.1 The depth and mechanical properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The web thickness and face reinforcement weight of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength.

5.7 Lower hull (SWATH)

5.7.1 Where the lower hull structure incorporates ring frames and attached shell laminate fitted between bulkheads or diaphragms, the scantlings of the lower hull shell stiffening may be derived from an established method for stiffening analysis or recognised standard for pressure vessels. Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. Copies of detailed calculations are to be submitted for consideration.

5.7.2 In general, the design load used is to be the design pressure from Pt 5,Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate. If other loads are considered to be of significance for the scantling determination these are to be taken into account.

5.8 Forefoot and stem

5.8.1 The scantlings and arrangements for the forefoot and stem construction are to be in accordance with Ch 3,5.11.

5.9 Transom knee

5.9.1 Transom knees are to be fitted in each hull as necessary in accordance with Ch 3,5.12.

■ *Section 6*
Double bottom structure

6.1 General

6.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for double bottom structure are to be determined in accordance with the procedures described in, or as required by Ch 3,6 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

6.1.2 The minimum thickness requirements detailed in Ch 3,2.1 are to be complied with as appropriate.

6.2 Keel

6.2.1 The breadth and thickness of plate keels are to comply with the requirements of 3.2.

6.3 Centreline girder

6.3.1 A centreline girder is to be fitted throughout the length of each hull. The web thickness, t_w, of centre girders of 'top-hat' type section is to be not less than as required by Ch 3,1.16. or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\ (0{,}073L_R + 3{,}64) \text{ mm within } 0{,}4L_R \text{ amidships}$$
$$= \sqrt{k_A}\ (0{,}073L_R + 2{,}73) \text{ mm at ends}$$

where

k_A and L_R are as defined in Ch 3,1.5.1.

6.3.2 The web thickness for a centreline girder of single plate laminate construction is to be two times the thickness as required by 6.3.1.

6.3.3 The overall depth of the centreline girder, d_{DB}, is not to be taken as less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the breadth of the floor at the upper edge, within a single hull, does not exceed 4,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side of the centreline girder, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of the floor at the upper edge, within a single hull, exceeds 4,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders, where fitted, are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.3 Under the main engine, girders extending from the bottom to the top plate of the engine seating are to be fitted. The height of the girders is not to be less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors are to be fitted.

6.4.4 Side girders are to have a minimum web thickness, t_w, as required by Ch 3,1.16 but not less than as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\ (0{,}064L_R + 4{,}32) \text{ mm}$$

where

k_A and L_R are as defined in Ch 3,1.5.1.

6.4.5 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 Plate floors may be of single skin, sandwich skin or 'top-hat' type construction, and are to comply with the requirements of 5.5 where applicable.

6.5.2 The web thickness, t_w, of non-watertight plate floors of 'top-hat' type section is to be not less than as required by Ch 3,1.16 or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\ (0{,}036L_R + 4) \text{ mm}$$

where

k_A and L_R are as defined in Ch 3,1.5.1.

6.5.3 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by 6.5.2.

6.5.4 The thickness of plate laminates which form the skins for plate floors of sandwich skin construction are in no case to be taken as less than 2 mm.

6.5.5 Additionally, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

6.5.6 Plate floors are generally to be continuous between the centre girder and the margin plate.

■ *Section 7* Bulkheads and deep tanks

7.1 General

7.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for bulkheads and deep tanks are to be determined in accordance with the procedures described in, or as required by Ch 3,7 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

7.1.2 The scantlings of non-watertight or partial bulkheads are in general to be as required for watertight bulkheads. Non-watertight or partial bulkheads supporting hull framing are to have scantlings equivalent to frames or web frames as appropriate, in the same position.

7.1.3 Sandwich wood bulkheads, plywood bulkheads or other forms of bulkhead construction will be considered on the basis of equivalent strength.

7.2 Longitudinal bulkheads within cross-deck structure

7.2.1 Longitudinal bulkheads are to be fitted within the cross-deck structure to prevent cross flooding and the spread of flame and smoke. The minimum number of such bulkheads is to be two for catamarans and four for trimarans. Quadrimarans and other craft of novel configuration will be specially considered.

7.2.2 The scantlings and arrangements of cross-deck longitudinal bulkheads are to be determined in accordance with the procedures described in Ch 3,7.3 and Ch 3,7.4 for bulkheads in mono-hull craft.

7.2.3 In addition the requirements of 7.4 in respect of global strength are to be complied with.

7.3 Transverse bulkheads within the cross-deck structure

7.3.1 The scantlings and arrangements of cross-deck transverse bulkheads are to be determined in accordance with the procedures described in Ch 3,7.3 and Ch 3,7.4 for bulkheads in mono-hull craft.

7.3.2 In addition the requirements of 7.4 in respect of global strength are to be complied with.

7.4 Additional strength required for global loadings

7.4.1 Where transverse bulkheads or deep tank bulkheads within the cross-deck structure are to assist in resisting torsional or bending loads between the hulls, then the watertight/deep tank bulkheads may be required to be additionally stiffened and the laminate or skin thicknesses may require to be increased. For hull girder strength requirements, *see* Ch 6,3.

7.4.2 Longitudinal bulkheads within the cross-deck structure that are to assist in maintaining the longitudinal strength of the vessel are to satisfy both bulkhead/deep tank and longitudinal strength requirements. This may require additional stiffening and increase in plate thickness requirements. For hull girder strength requirements, *see* Ch 6,3.

7.4.3 Where longitudinal or transverse cross-deck bulkheads/deep tanks are to carry global loads, detailed calculations are to be submitted.

7.4.4 For longitudinal or transverse cross-deck members carrying global loads, consideration is to be given to stiffener arrangement, alignment, and continuity in order to maximise the rigidity and stiffness of the structure, in resisting the torsional/bending loads. Due consideration is to be given to the wrinkling and buckling of the skins of sandwich plate laminates. Discontinuity of structural bulkheads is to be avoided.

7.5 Access

7.5.1 Access through the cross-deck structure may be permitted, provided that the global strength requirements are satisfied. Cut-outs through the bulkhead are not to exceed 50 per cent of its depth. The edges of cut-out in sandwich panels are to be suitably reinforced while those of single skin construction are to be sealed.

7.5.2 Where the cross-deck structure acts as a watertight bulkhead pipe or cable runs through, the watertight bulkheads are to be fitted with suitable watertight glands.

7.6 Local strength

7.6.1 Bulkheads that form the cross-deck structure are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.7 Integral/deep tanks within cross-deck structure

7.7.1 Where the cross-deck structure forms the boundaries of deep tanks, the scantlings of these boundaries are to satisfy both deep tank and global strength requirements. For general and structural requirements for deep tanks, *see* Ch 3,7.4. For global considerations of strength, *see* Ch 6,3.

■ *Section 8* Deck structures

8.1 General

8.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for deck structures are to be determined in accordance with the procedures described in, or as required by Ch 3,8 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

8.1.2 Deck structures are to comply with the minimum thickness requirements of Section 2.

8.1.3 Special attention is to be given to the connections of primary transverse beams to hull side web frames in order to provide adequate load distribution and avoid stress concentrations.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Design loads to be applied for cross-deck scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 5.

8.2 Arrangements

8.2.1 Deck structures are to comply with the longitudinal and transverse global strength requirements given in Chapter 6.

8.3 Symbols and definitions

8.3.1 The term ‘cross-deck’ is used in this Section for the bridging deck, connecting two or more hulls, carrying global transverse loads. *See also* 1.5.4.

8.4 Cross-deck laminate

8.4.1 The bending moment assumed to be carried by the cross-deck laminate is to be not less than that determined by Ch 3,1.9.1, using the design pressure from Pt 5, Ch 3,3.1, or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 8.4.2 and 8.4.4 respectively.

8.4.2 An estimate of the thickness of **strength/weather deck single skin laminate** is to be determined from Ch 3,1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.12.3 and Ch 3,1.12.4, *see also* LR’s *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.4.3 In no case is the minimum thickness of single skin laminate to be taken as less than 4 mm.

8.4.4 An estimate of the stiffness, EI, thickness of single skin laminate for outer and inner skins of the **strength/weather deck sandwich panels** and the thickness of core material is to be determined from Ch 3,1.13.2 and Ch 3,1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.13.7 and Ch 3,1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.4.5 In no case are the minimum thicknesses of laminate which form the skins of a sandwich laminate to be taken as less than 3 mm and 2 mm for the outer and inner skins respectively.

8.4.6 Special consideration may be given to laminate thicknesses lesser than those required by 8.4.3 and 8.4.5, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided and the equivalent impact resistance is demonstrated as required by Ch 3,2.8.2.

8.4.7 The scantlings of watertight cockpits are to be of equivalent strength to those for the strength/weather deck, *see also* Part 4.

8.4.8 It is recommended that working areas of the weather deck have an anti-slip surface.

8.4.9 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* Ch 3,2.9.

8.5 Cross-deck stiffening

8.5.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the cross-deck primary stiffeners are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1, or Pt 5, Ch 4.3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (a).

8.5.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the cross-deck secondary stiffeners are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1, or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.5 in Chapter 3 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.5.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

8.5.4 The geometric properties of stiffener sections are to be calculated in accordance with Ch 3,1.15 using an effective width of attached laminate as given in Ch 3,1.7.

8.5.5 For cases where there may be excessive rotations or deflections at supports or where the lateral pressure distribution is non-uniform, the above scantlings may have to be increased appropriately.

8.5.6 Where stiffeners are subject to concentrated loads such as pillars, the concentrated loads are to be superimposed on the lateral pressure and strength calculations carried out to demonstrate compliance with the deflection and stress criteria given in Table 7.2.1 in Chapter 7 and Table 7.3.1 in Chapter 7.

8.5.7 Where the floating frame system is used, the effect of the plating attached to the stiffening members is to be ignored when calculating the required section stiffness, EI, of the primary stiffening members, i.e. the full stiffness, EI, is to be provided by the primary stiffening members only.

8.5.8 Openings in the cross-deck for hatches etc., are to comply with the requirements of Ch 3,8.12.

8.6 Novel features

8.6.1 Where the cross-deck structure is of unusual design, form or proportions, the scantlings are to be determined by direct calculation, *see* Ch 3,2.7.

■ *Section 9* Superstructures, deckhouses, bulwarks and pillars

9.1 General

9.1.1 The scantlings and arrangements for superstructures, deckhouses and bulwarks are to be determined in accordance with the procedures described in, or as required for mono-hull craft indicated in Ch 3,9.

9.1.2 The scantlings and arrangements for pillars are to be determined in accordance with the procedures described in, or as required for mono-hull craft indicated in Ch 3,10.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to both mono-hull and multi-hull craft of composite construction.

1.2 Symbols and definitions

1.2.1 The symbols in this Section are as defined in Ch 3,1.5.1 and in the appropriate sub-Section.

■ *Section 2* Special features

2.1 Water jet propulsion systems – Construction

2.1.1 The requirements for the construction and installation of water jet units apply irrespective of rated power.

2.1.2 Water jet ducts may be fabricated as an integral part of the hull structure, or as a bolted-in unit. In either case, detailed plans indicating dimensions, scantlings and materials of construction of the following are to be submitted in triplicate:

(a) Arrangement of the system including intended method of attachment to the hull and building-in, geometry of tunnel, shell opening, method of stiffening, reinforcement, etc.
(b) Shaft sealing arrangements.
(c) Details of any shafting support or guide vanes used in the water jet system.
(d) Details and arrangements of inspection ports, their closing appliances and sealing arrangement, etc.
(e) Details and arrangements of protection gratings and their attachments.

2.1.3 When submitting the plans requested in 2.1.2, details of the designers' loadings and their positions of application in the hull are to be submitted and are to include maximum applied thrust, moments and tunnel pressures for which approval of the propulsion system is sought.

2.1.4 All materials used in construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.5 Aluminium alloys, where used, are to be of suitable marine grades in accordance with the requirements of Part 7.

2.1.6 Irrespective of the material used, the strength and supporting structure of all tunnels are to be examined by direct calculation procedures which are to be submitted. In no case are the scantlings to be taken as less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

2.1.7 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of the guard are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

2.1.8 The inlet profile of the tunnel is to be so designed as to provide a smooth uptake of water over the range of craft operating trims and avoid significant separation of the flow into the rotating machinery.

2.1.9 The leading edges of FRP tunnels are to be additionally reinforced by suitable means. Proposals are to be submitted as required by 2.1.2.

2.1.10 Single or multiple water jet unit installations having a total rated power in excess of 500 kW are to be contained within their own watertight compartment. Other arrangements for maintaining watertight integrity may be specially considered depending on the size and installation layout.

2.1.11 For details of machinery requirements, *see* Pt 10, Ch 2, Machinery Requirements.

2.2 Water jet propulsion systems – Installation

2.2.1 Standard units built for 'off the shelf' supply and which include the duct are to be installed strictly in accordance with the manufacturer's instructions, *see also* 2.1.4.

2.2.2 Integral water jet ducts are to be constructed in accordance with the manufacturer's requirements and the relevant plans submitted as required by 2.1.2.

2.2.3 Where load is transmitted into the transom and/or bottom shell, the thickness of the laminate adjacent to the jet unit is to be increased. The increase in thickness is to be not less than 50 per cent of the calculated transom and bottom laminate thicknesses respectively or 12 mm, whichever is the greater. Such reinforcement is to extend beyond the surrounding stiffening structure.

2.2.4 For 'bolted in' units, hull receiving rings are to be of a material compatible with the hull. Scantlings of the receiving rings are to be as required by the jet unit manufacturer and suitably edge prepared prior to bonding in place. The receiving ring is to be installed using an approved laminating procedure. Where a manufacturer's specification is not provided, full details are to be submitted.

2.2.5 Bolt sizes and spacings are to be specified by the manufacturer, and are to be of suitable marine grade, insulated as appropriate and locked by suitable means.

2.2.6 Where studs are proposed for the receiving ring(s), the remaining thickness below the depth of blind tap is to be not less than 0,2 times the thickness of the receiving ring or 5 mm whichever is the greater. Bottoms of all blind taps are to be free of sharp corners.

2.2.7 The use of approved alignment resins may be considered where accurate seating and faying surfaces are required. Details are to be submitted for consideration and approval.

2.2.8 Where a water jet unit forms an integral part of the hull structure, such units are to be installed using an approved laminating procedure and in accordance with the manufacturer's instructions. Materials to be laminated are to be of compatible specifications.

2.2.9 Water jet units transmitting thrust into the transom structure are to be supported by a system of radial, athwartship and vertical stiffening. Drawings are to be accompanied by a set of detailed structural calculations. Where complex installations are proposed, a finite element model may be submitted in lieu of direct calculations.

2.2.10 Water jet units transmitting thrust to a bottom shell connection or intermediate tunnel connection are to be supported by additional stiffening, the details and calculations for which are to be submitted.

2.2.11 In general, sandwich skin laminates in way of water jet installations are to be brought together to form single skins complying with 2.2.3. Proposals to use sandwich construction in way of installations will be specially considered, subject to the use of appropriate structural core materials and direct calculations being submitted in support.

2.2.12 Exposed edges of laminates subject to water flow are to be over laminated and protected by suitable means; proposals are to be submitted for consideration.

2.2.13 Where the jet-unit is an FRP premoulding of an approved type, the surface of the unit is to be suitably abraded and degreased prior to installation in the mould tool and subsequent over laminating of the main hull structure. Particular care is to be given to material compatibility of the resin system used for the premould and main hull laminate.

2.3 Foil support arrangements

2.3.1 The materials and construction of the lifting surface will be considered on a case by case basis.

2.3.2 The design and performance of the lifting surface is outside the scope of classification. However, when submitting structural plans for the hull connection installation, the designer/Builder is to define:

(a) Operating mode, i.e. fully submerged or surface piercing.
(b) Maximum operational speed for which approval is sought.
(c) Maximum, direct, bending, shear and torque loads generated by the foil at the point of attachment(s).
(d) The type of profile or section used, e.g. N.A.C.A.
(e) Supply of lift/drag profile.
(f) If the foil is fixed, moveable or retractable.
(g) If the foil is fitted with control surfaces.
(h) If the vertical leg(s) act as a rudder(s).
(j) If shaft liners are carried to the foils at which support arrangements are provided.
(k) If water intakes/scoops are fitted.
(l) If propulsion units are fitted.

2.3.3 The scantlings and arrangements of foils and their supporting structure will be required to be specially considered in the following cases where:

(a) Propulsion units are incorporated within the foil.
(b) Foils carry shaft support arrangements.
(c) The foils are of novel design.

2.3.4 Where fully submerged foils are 'built-in' to the hull, the attachment area is to be contained within a watertight compartment. The structural arrangements of 2.4 are to be complied with as appropriate.

2.3.5 Where foils are to be bolted to the structural foundation and not 'built in', calculations are to be submitted. These are to demonstrate that the effect of loading arising from high speed impact, grounding, fouling, etc., is limited to failure of the bolted connection. In all cases the structural and watertight integrity of the craft is to be maintained.

2.3.6 Attachment points of foils are in all cases to be contained within a watertight compartment.

2.3.7 Foils attached by rivetted means are, in addition, to comply with Pt 7, Ch 2,4.26.

2.3.8 Bow fairing doors fitted on forward retracting bow foils are to be weathertight and are to comply with the requirements of Pt 3, Ch 4.

2.3.9 Aft bulkheads of bow foil compartments are to comply with the requirements for collision bulkheads as detailed in Ch 3,7.6.

2.3.10 Hydraulically operated retracting systems are to be equipped with low pressure alarms, together with a manual system of operation in the event of system failure.

2.3.11 A mechanical locking system is to be provided on retracting systems when the system is in both the operational and 'stowed' conditions.

2.4 Surface drive mountings

2.4.1 Transoms through which surface drive systems pass and which are required to carry thrust, significant weight, torque, moment, etc., are to be adequately reinforced.

2.4.2 The thickness of transom laminate is to be not less than 50 per cent greater than the adjacent plating or as advised by the drive manufacturer, whichever is the greater.

2.4.3 Steering rams are to be mounted on suitably reinforced areas of laminate supported by additional internal stiffening; details are to be submitted for consideration.

2.5 Sea inlet scoops

2.5.1 Sea inlet scoops may be integral with or an appendage to the hull.

2.5.2 Scoops are to be suitably positioned to minimise ventilation.

2.5.3 Suitable protective arrangements are to be provided to minimise the ingress of debris. The net area through the proposed arrangement is to be not less than twice that of the valves connected to the scoop. Provision is to be made for clearing the scoops by the use of suitable means; proposals are to be submitted.

2.5.4 Scoops are to be contained within a watertight compartment.

2.5.5 The laminate thickness in way of integral scoops is to be not less than 50 per cent greater than that of the adjacent shell laminate, with additional reinforcement at the leading edge.

2.5.6 For all composite construction, scoops are to be fitted as bolted appendages.

2.5.7 For craft navigating in ice, the arrangements will be specially considered on an individual basis.

2.6 Crane support arrangements

2.6.1 Crane pedestals are to be efficiently supported and, in general, are to be carried through the deck and satisfactorily scarfed into the surrounding structure. Alternatively, crane pedestals may comprise of a foundation, in which case the foundation and its supporting structure are to be of substantial construction. Proposals for other support arrangements will be specially considered.

2.6.2 The pedestal or proposed arrangement is to be designed with respect to the worst possible combinations of loads resulting from the crane self weight, live load, wind and crane accelerations together with those resulting from the craft's heel and trim. The designer's calculations for loadings are to be indicated on the plans to be submitted.

2.6.3 Stowage arrangements are to be taken into account when calculating the loads applied to the pedestal.

2.6.4 When submitting plans for the proposed foundation, the designer is to include his design calculations covering the parameters indicated in 2.6.2.

2.6.5 The deck laminate is to be additionally reinforced in way of crane foundations. The thickness of reinforcement is to be that required by the designer's calculations but in no case less than 50 per cent the thickness of the adjacent plating.

2.6.6 Laminate tapers are to be in accordance with Ch 2,3.9.

2.7 Skirt attachment

2.7.1 The design and scantlings of the skirt are, in general, outside the scope of classification, however the designers/builders are to submit their proposals in respect of the attachment detail. The following supporting information is to be submitted:

(a) Cushion pressure,
(b) Calculations demonstrating that the effect of damage to the flexible membrane and/or the retaining section arising from high speed impact, grounding, fouling, etc., will not compromise the structural and watertight integrity of the craft.

2.7.2 The skirt is to be securely attached around its periphery. The supporting structure is to be suitably reinforced by the use of tapping plates incorporated into the laminate.

2.7.3 Where the skirt is retained by bolting the retaining bars are to be as long as practicable, with the fasteners being spaced not more than 50 mm apart.

2.7.4 Where the design of the skirt is such that the flexible edge is retained by the use of a pre-formed channel, only the bolted connection of the preform to the hull structure is to be considered.

2.8 Trim tab arrangements

2.8.1 The shape, design and scantlings of the trim tab are outside the scope of classification, however Lloyd's Register (hereinafter referred to as 'LR') is concerned with their attachment to the hull structure.

2.8.2 The designer/Builder is to submit the following:

(a) Detailed calculations indicating the maximum lift force generated by the tab for which acceptance is sought together with the corresponding speed and displacement.
(b) Details of the hull attachment and loadings in way for the trim tab and actuation system.
(c) Details and calculations of the local internal reinforcement to resist the loading in way of the attachment.

2.8.3 Bearing materials used are to be of an approved type.

2.8.4 Fully submerged retractable trim tabs will be specially considered on a case by case basis.

2.9 Spray rails

2.9.1 Spray rails are, in general, to be integrated into the hull structure but may be added in the form of an appendage on completion of the hull shell.

2.9.2 Where spray rails are integrated, they are to have a laminate thickness not less than the adjacent bottom shell and additionally have section properties equivalent to that required for a longitudinal stiffener in the same position.

2.9.3 Where spray rails are added as an appendage, they are to be attached in accordance with an approved bonding/laminating procedure and are additionally to comply with the strength requirements of 2.9.2. Composite preforms bonded to the outer hull are to be manufactured and bonded using approved materials, compatible with the hull laminate.

2.9.4 Spray rails are to be supported by the internal stiffening arrangements and by additional local reinforcement as necessary.

2.9.5 In no case are the toes of spray rails to terminate on unsupported shell laminate.

2.9.6 In sandwich construction the outer skin is to be a smooth continuous surface, with spray rails attached as required by 2.9.3.

2.10 Other lifting surfaces

2.10.1 Other lifting surfaces not specifically covered by the Rules will be individually considered on the basis of submitted direct calculations.

2.10.2 Structure or hull shapes above the running waterline designed to generate aerodynamic lift may be individually considered on a case by case basis.

2.10.3 Aerodynamic, hydrodynamic and aero-hydrodynamic stability are outside the scope of classification and are subject to the approval of the National Administration concerned.

2.11 Propeller ducting

2.11.1 Where propellers are fitted within ducts/tunnels the laminate weight in way of the blades is to be increased by 50 per cent.

2.11.2 The tunnel wall in way of the propeller blades is to be additionally stiffened.

2.12 Ride control ducting and installation for Surface Effect Ships (SES)

2.12.1 Ducts penetrating the side inboard shell plating are to comply with the scantling requirements for side inboard structures, over their entire length, in the appropriate material.

2.12.2 Ducts penetrating the wet-deck are to comply with the scantling requirements for wet-deck structures over their entire length, in the appropriate material.

2.12.3 Open ends of ducts are to be fitted with a suitable protective grille.

2.12.4 The vent assembly, its design, construction and operation is outside the scope of classification and is the responsibility of the ride control system designer.

2.12.5 Details of the installation and securing arrangements of the vent valve assembly into the duct are to be submitted for approval.

■ *Section 3* **Vehicle decks**

3.1 General

3.1.1 Where it is proposed to construct vehicle decks in FRP composite materials, each case will be subject to individual consideration. The scantlings are to be determined by direct calculation or on the basis of the requirements of Chapter 3, in conjunction with the procedures, loadings and general requirements for vehicle decks of aluminium alloy construction, as indicated in Pt 7, Ch 5.

3.1.2 It is recommended that single skin laminate construction incorporating longitudinal or transverse stiffening be adopted. Where it is proposed to use sandwich skin construction, particular care is to be given to the selection of the core material. Such proposals will require to be specially considered, and testing may be required to demonstrate the suitability of the panels.

3.1.3 The deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, the hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required for a weather or cargo deck or hatch cover, as applicable.

3.1.4 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Builder. These details are to include axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. The vehicle types and wheel loads for which the vehicle decks, including hatch covers where applicable, have been approved are to be included in the craft's documentation and contained in a notice displayed on each deck. For design purposes, the wheel loading is to be taken as not less than 3,0 kN.

3.1.5 The scantling requirements are based on structural strength and limitations on stress and deflection, with no allowance made for wear and tear. Local reinforcement is to be fitted as necessary, particularly in way of vehicle lanes and passenger routes.

3.1.6 Deck fittings in way of vehicle lanes are to be recessed.

3.2 Securing arrangements

3.2.1 Details of the loads and connections to the hull of vehicle securing arrangements are to be indicated on the plans submitted with the Designer's calculations.

3.3 Access

3.3.1 Where access to the vehicle deck is provided by bow, side and stern doors, these openings are to comply with the requirements of Pt 3, Ch 4,4.

3.3.2 Doors providing pedestrian access between vehicle decks and accommodation spaces are to be gastight, and have scantlings and fire restricting characteristics equivalent to the surrounding structure, *see also* Part 17.

3.4 Hatch covers

3.4.1 The scantlings and arrangements of hatch covers located within vehicle decks are to be not less than those required by the Rules for the supporting structure in which such hatches are fitted. In general, the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

3.4.2 In no case, however, are the scantlings of plate or sandwich laminates and stiffeners to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.4.3 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of plating and stiffeners may be determined by direct calculations using a two-dimensional grillage determination.

3.5 Heavy and special loads

3.5.1 Where heavy or special loads are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered on the basis of submitted calculations.

3.5.2 Due account is to be taken of the acceleration levels due to craft motion applicable to particular items of heavy mass such as vehicles, containers, pallets, etc.

3.6 Direct calculations

3.6.1 LR will consider direct calculations for the derivation of vehicle deck scantlings as an alternative and equivalent to those derived by Rule requirements. The assumptions made and the calculation procedures used are to be submitted for appraisal in accordance with Pt 3, Ch 1,2.

■ *Section 4* Movable decks

4.1 Classification

4.1.1 Movable decks other than those described in 4.1.2 are not a classification item, although consideration is to be given to the associated supporting structure. Where movable decks are fitted, it is recommended that they are to be based on the requirements of this Section.

4.1.2 At the Owner's or Builder's request, however, movable decks will be included as a classification item, and the class notation **Removable decks** will be entered in the *Register Book*. In such cases, all movable decks on board the craft are to comply with the requirements of this Section.

4.2 Arrangements and designs

4.2.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

4.2.2 Positive means of control are to be provided to secure decks in the lowered position.

4.2.3 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

4.2.4 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

4.2.5 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc., are to be submitted for consideration.

4.3 Loading

4.3.1 The loading requirements for movable decks are to be in accordance with 3.1.

4.3.2 Where it is proposed also to use the decks for general cargo, the design loadings are to be submitted for consideration.

4.4 Scantling determination

4.4.1 The scantlings and arrangements of movable decks are to be not less than required by the Rules for the supporting structure in which they are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

4.5 Deflection

4.5.1 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during loading or unloading operations.

4.6 Direct calculations

4.6.1 As an alternative to the requirements of 4.3 to 4.5, the structure may be designed on the basis of a direct calculation using a grillage idealisation. The method adopted and the stress levels proposed for the material of construction are to be submitted for consideration, *see also* Pt 3, Ch 1,2.

■ *Section 5* Helicopter landing areas

5.1 General

5.1.1 Where it is proposed to construct helicopter landing areas in FRP composite materials, each case will be subject to individual consideration.

5.1.2 Helicopter landing areas are to be designed to suit the largest helicopter type which it is intended to use. In general, the diameter of the landing area is to be not less than 1,25 times the rotor diameter.

5.1.3 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the craft.

5.1.4 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of helicopters to be used are also to be indicated. Details of the helicopter types to be used are to be included in the craft's documentation, and be contained in a notice displayed on the helicopter landing deck.

5.1.5 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

5.1.6 The requirements for fire protection, detection and extinction are to comply with Part 17. Special consideration is to be given to the insulation standard if the space below the helicopter deck is a high fire-risk space.

5.1.7 It is recommended that single skin laminate construction incorporating longitudinal or transverse stiffening is to be adopted. Where it is proposed to use sandwich skin construction, particular care is to be given to the selection of the core material; such proposals will require to be specially considered, and testing may be required to demonstrate the suitability of the panels.

5.2 Symbols

5.2.1 The symbols in this Section are as defined in Ch 3,1.5.1 and in the appropriate sub-Section.

5.3 Arrangements

5.3.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the helicopter, and is to be approached by a clear landing and take-off sector complying in extent with the applicable regulations.

5.3.2 The landing area is to be free of any projections above the level of the deck. Projections in the zone surrounding the landing area are to be kept below the heights permitted by the regulations.

5.3.3 Suitable arrangements are to be made to minimise the risk of personnel or machinery sliding off the landing area. A non-slip surface and anchoring devices are to be provided.

5.3.4 Arrangements are to be made for drainage of the platform, including drainage of spilt fuel.

5.3.5 Details of the connections to the hull of helicopter securing arrangements are to be submitted for approval.

5.3.6 Engine uptake arrangements are to be sited such that exhaust gases cannot be drawn into helicopter engine intakes during helicopter take off or landing operations.

5.4 Loadings

5.4.1 The load cases to be investigated are to be not less than those required by Pt 7, Ch 5,6 for helicopter landing areas of aluminium alloy construction.

5.4.2 The proposed loadings are to be agreed with LR prior to scantling analysis and submission of structural plans for appraisal.

5.4.3 Details of the deck loading resulting from the proposed stowage arrangements of helicopters are to be supplied by the Builder. These details are to include the axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the helicopter. For design purposes the wheel loading is to be taken as not less than 3,0 kN (0,3 tonne-f).

5.4.4 Where it is proposed also to use the decks for general cargo or other alternative use, the design loadings are to be submitted for consideration.

5.5 Scantlings

5.5.1 The scantlings and arrangements of helicopter landing areas are to be not less than those required by the Rules for the supporting structure in which the helicopter landing areas are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

■ *Section 6* Strengthening requirements for navigation in ice conditions

6.1 General

6.1.1 The strengthening requirements detailed in this Section are applicable to craft, other than those assigned the notation **HSC** and/or **LDC** (*see* Pt 1, Ch 2), intended for operation in light first year ice conditions in areas other than the northern Baltic corresponding to unbroken level ice of thickness not greater than 0,4 m.

6.1.2 Craft complying with the requirements of this Section, in addition to the requirements for sea-going service where applicable, will be eligible for the special features notation **Ice Class 1D**. Alternatively, a Special Duties Notation may be assigned indicating that the craft has been additionally strengthened for duties in ice (*see* Pt 1, Ch 2,3.8.3).

6.1.3 Craft designed to operate in ice conditions other than those detailed in 6.1.1 are to comply with Part 8 of the Rules for Ships.

6.1.4 The requirements of this Section are applicable to both longitudinally and transversely framed craft and concern the shell laminate and framing in the forward region, the stem, sternframe, rudder and the steering gear.

6.1.5 The vertical extent of the ice strengthening is related to the ice light and ice load waterlines, which are defined in 6.2. The maximum and minimum Ice Class draughts at both the fore and aft ends will be stated on the Class Certificate.

6.1.6 The requirements of this Section assume that when approaching ice infested waters the craft's speed will be reduced appropriately. The vertical extent of ice strengthening for craft intended to operate in ice conditions at speeds exceeding 15 knots will be specially considered.

6.1.7 The ballast capacity of propeller-driven craft is to be sufficient to give adequate propeller immersion in all ice navigating conditions without trimming the craft in such a manner that the actual waterline at the bow is below the ice light waterline. Ballast tanks situated above the ice light waterline and adjacent to the shell, which are intended to be used in ice navigating conditions, are to be provided with heating pipes.

6.1.8 Side scuttles are not to be situated in the ice belt.

6.2 Definitions

6.2.1 The Ice Load Waterline is that corresponding to the Fresh Water Summer Loadline.

6.2.2 The Ice Light Waterline is that corresponding to the lightest condition in which the craft is expected to navigate in ice.

6.2.3 The Ice Load Waterline and the Ice Light Waterline are to be indicated on the plans. For navigation in certain geographical areas, the relevant National Authority may require the maximum Ice Class draught to be marked on the craft in a specified manner.

6.2.4 The Main Ice Belt Zone extends vertically from 500 mm below the Ice Light Waterline to 400 mm above the Ice Load waterline and horizontally from the stem to $0{,}02L_R$ m aft of the point at which the deepest load waterline reaches its greatest breadth. L_R is as defined in Pt 3, Ch 1,6.2.1.

6.3 Powering of ice strengthened craft

6.3.1 Ice strengthened craft are assumed to be capable of developing sufficient thrust to permit continuous mode icebreaking at a speed of at least five knots in ice having a thickness of 0,4 m and a snow cover of at least 0,3 m.

6.4 Shell laminate

6.4.1 It is assumed that single skin laminate construction incorporating longitudinal or transverse stiffening will be adopted. Where it is proposed to use sandwich skin construction, particular care is to be given to the selection of the core material; such proposals will require to be specially considered, and testing may be required to demonstrate the suitability of the panels.

6.4.2 In way of the main ice belt zone, the thickness of the shell laminate is to be determined by direct calculation. A copy of these calculations is to be submitted for consideration.

6.4.3 Changes in laminate thicknesses are to take place gradually, and in no case is the length of taper to be less than 20 times the difference in thickness. Additionally individual plys of the laminate are to be arranged such that any delamination will be directed to the outer surface of the laminate.

6.4.4 If the weather deck in any part of the craft is situated below the upper limit of the ice belt, the bulwark is to be reinforced to the same degree as the shell plating in the main ice belt.

6.5 Shell framing

6.5.1 Ice framing is to extend to a minimum distance of 1000 mm above the Ice Load Waterline and 1600 mm below the Ice Light Waterline between the stem and $0{,}02L_R$ m aft of the point at which the deepest load waterline reaches its greatest breadth. L_R is as defined in Pt 3, Ch 1,6.2.1.

6.5.2 The web thickness for ice framing members of top-hat or plate section is to be determined by direct calculation. A copy of these calculations is to be submitted for consideration.

6.5.3 Ice frames are to be attached to the shell plating by double primary bonding angles in accordance with Ch 3,1.18. The web area of ice frames is to be maintained; air and drain holes are to be kept to a minimum.

6.5.4 Main and intermediate frames within the minimum extent of ice framing are to be efficiently supported to prevent tripping. The distance between anti-tripping supports is not to exceed 1000 mm.

6.5.5 The bending moment assumed to be carried by the ice framing stiffening member is not to be taken as less than 50 per cent greater than that required by the appropriate Section of the Rules for the stiffening member subjected to hydrostatic or pitching pressure whichever is the greater.

6.6 Stem construction

6.6.1 The stem is to be additionally protected/ reinforced by a metallic shoe or other equivalent arrangement. The shoe/reinforcement is to extend from the keel plate to 750 mm above the ice load waterline and is to be internally strengthened by closely spaced floors, brackets or webs. Details of such protection and the method of attachment are to be submitted for consideration.

6.6.2 Attachment by mechanical means such as bolting or other methods is not to impair the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable.

6.7 Stern construction

6.7.1 A transom stern is not normally to extend below the ice load waterline. Where this cannot be avoided, the transom is to be kept as narrow as possible and the scantlings of plating and stiffeners are to be as required for the midship region.

6.8 Bossings and shaft struts

6.8.1 For craft with two or more propellers, shafting and sterntubes are generally to be enclosed within plated bossings. If detached supporting struts are necessary, their design, strengthening and attachment to the hull will be specially considered, *see also* Pt 3, Ch 3,3.4.

6.9 Rudder and steering arrangements

6.9.1 Rudder posts, rudder horns, sole pieces, rudder stocks and pintles are to be dimensioned in accordance with Pt 2, Ch 3. The speed used in the calculations is to be the service speed or 14 knots, whichever is the greater.

6.9.2 The thickness of rudder plate laminate and webs is to be increased by 50 per cent over the requirements of Pt 3, Ch 3,2.

6.9.3 Due regard is to be paid to the method of securing the rudder in the centreline position when backing into ice. Where possible, rudder stoppers working on the blade or rudder head are to be fitted.

6.9.4 Where steering nozzles are fitted, the thickness of the shroud plating is, in general, to include an abrasion allowance of 20 per cent.

6.9.5 The scantlings of the stock, pintles, gudgeon and sole pieces associated with the nozzle are to be increased on the basis given in 6.9.1. However, the diameter of the nozzle stock is to be not less than that calculated in the astern condition taking the astern speed as 7 knots or the actual astern speed, whichever is the greater.

6.9.6 Nozzles with articulated flaps will be subject to special consideration.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements for longitudinal and transverse global strength for both mono-hull and multi-hull craft of composite construction, are contained within this Chapter. Due consideration is taken of the dynamic effects, where appropriate, in both the crest and trough wave landing conditions.

1.2 Symbols and definitions

1.2.1 Unless specified otherwise the symbols used in this Chapter are defined as follows:

a_i = cross sectional area of the individual ply, *i*, in m^2
E_{ci} = compressive modulus of individual ply, *i*, in N/mm^2
E_i = E_{ti}, or E_{ci} of the individual ply *i*, relative to its position above or below the neutral axis, in N/mm^2
E_{ti} = tensile modulus of individual ply, *i*, in N/mm^2
I_i = inertia of the of individual ply, *i*, about the neutral axis, in mm^4
M_R = the appropriate Rule bending moment, as defined in Pt 5, Ch 5,5
Q_R = the appropriate Rule shear force, as defined in Pt 5, Ch 5,5
x_i = the distance to the centre of area of the individual ply, *i*, from the outer surface of the keel plate laminate, in metres
y_i = vertical distance from the hull transverse neutral axis to the centre of the individual ply, in metres
y_{NA} = the distance of the neutral axis, from the outer surface of the keel plate laminate, in metres.
$\Sigma(E_i I_i)_H$ = total $(EI)_H$ (stiffness) for the hull midship section, in Nm^4/mm^2
σ_{ci} = compressive stress within an individual element, *i*, in N/mm^2
σ_{ti} = tensile stress within an individual element, *i*, in N/mm^2
τ_H = shear stress at any position along the length of the craft, in N/mm^2

L_R and *B* are as defined in Pt 3, Ch 1,6.2.

1.2.2 The strength deck is to be taken as follows:

(a) Where there is a complete upper deck the strength deck is the upper deck.
(b) Where the upper deck is stepped, as in the case of raised quarterdeck craft, the strength deck is stepped as shown in Fig. 6.1.1.

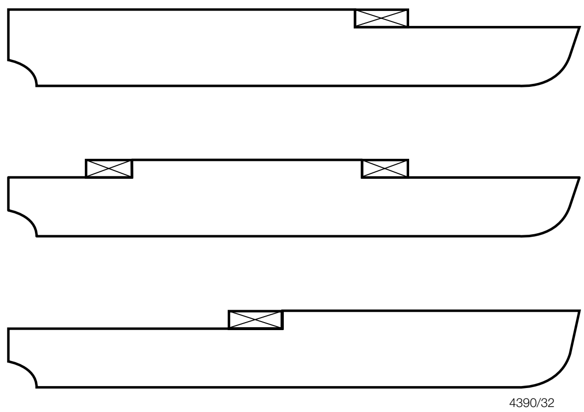


Fig. 6.1.1 Strength deck

1.3 General

1.3.1 The additional pressures arising from the influence of the global loading are considered in the determination of the longitudinal strength requirements for local and secondary stiffening and bottom shell laminate.

1.3.2 All continuous longitudinal structural material is to be included in the calculation of the stiffness, $(EI)_H$, of the hull midship section, and the lever, y_i, is to be measured vertically from the neutral axis to the centre of the individual ply, *i*. The inertia of an individual horizontal ply, *i*, about its own axes is to be ignored.

1.3.3 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performance.

1.3.4 In general, superstructures or deckhouses will not be accepted as contributing to the global longitudinal or transverse strength of the craft. However, where it is proposed to include substantial, continuous stiffening members, special consideration will be given to their inclusion on submission of the designer's/builder's calculations. Such calculations are to make due allowance for superstructure efficiency. *See also* Pt 7, Ch 6,2.5.

1.3.5 Where continuous deck longitudinals or deck girders are arranged above the strength deck, special consideration may be given to the inclusion of their sectional area in the calculation of the hull stiffness $(EI)_H$. The lever is to be taken to a position corresponding to the depth of the longitudinal member above the moulded deckline at side amidships. Each such case will be individually considered.

1.3.6 Adequate transition brackets are to be fitted at the ends of effective continuous longitudinal strength members in the deck and bottom structures.

1.3.7 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section stiffness requirements given in 2.2 are to be maintained within 0,4L_R amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the 0,4L_R part, bearing in mind the desire not to inhibit the vessel's loading and operational flexibility. L_R is as defined in 1.2.1.

1.4 Openings

1.4.1 Deck openings having a length in the fore and aft directions exceeding 0,1*B* m or a breadth exceeding 0,05*B* m, are always to be deducted from the sectional areas used in the section stiffness calculation. *B* is as defined in 1.2.1.

1.4.2 Deck openings smaller than stated in 1.4.1 including manholes, need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths (*see* 1.4.3), in one transverse section does not exceed 0,06 ($B_1 - \Sigma b_1$).
where

B_1 = breadth of craft at section considered
Σb_1 = sum of breadths of deductible openings.

Where a large number of deck openings are proposed in any transverse space, special consideration will be required.

1.4.3 Where calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in Fig. 6.1.2. The shadow area is obtained by drawing two tangent lines to an opening angle of 30°. The sections to be considered are to be perpendicular to the centreline of the ship and are to result in the maximum deduction in each transverse space.

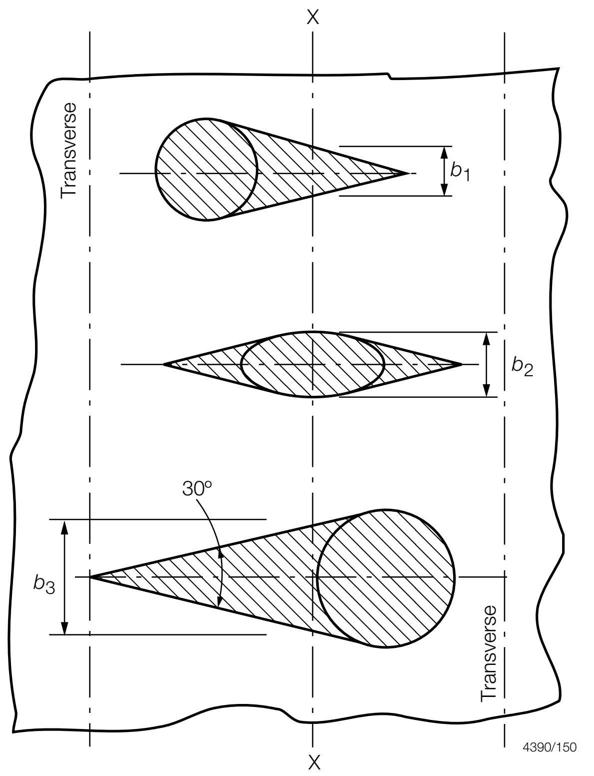
1.4.4 Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth or 75 mm whichever is the lesser.

1.4.5 Openings are considered isolated if they are spaced not less than 1 m apart.

1.4.6 A reduction for drainage holes and scallops in beams and girders, etc., is not necessary so long as the original section stiffness at deck or keel is reduced by no more than three per cent.

1.5 Direct calculation procedure

1.5.1 In direct calculation procedures capable of deriving the wave induced loads on the ship, and hence the required modulus, account is to be taken of the ship's actual form and weight distribution.



Total equivalent breadth of small openings at XX = $b_1 + b_2 + b_3$

Fig. 6.1.2 Isolated openings

1.5.2 Lloyd's Register's (hereinafter referred to as 'LR') direct calculation method involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval are normally to contain these three elements and produce similar and consistent results when compared with LR's methods.

1.6 Approved calculation systems

1.6.1 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from LR, calculations using the system for a particular ship may be submitted.

1.7 Information required

1.7.1 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR's standard format where appropriate:

(a) General arrangement and capacity plan or list, showing details of the volume and position of centre of gravity of all tanks and compartments.
(b) Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull. A lines plan and/or Tables of offsets may also be required.

(c) Details of the calculated lightweight and its distribution.
(d) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions. It is recommended that this information be submitted in the form of a preliminary Loading Manual, and that it includes the calculated still water and dynamic bending moments and shear forces.

1.8 Loading guidance information

1.8.1 Sufficient information is to be supplied to the Master of every craft to enable him to arrange loading in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

■ *Section 2* Hull girder strength for mono-hull craft

2.1 General

2.1.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 40 m, covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

2.1.2 For craft of ordinary hull form with a Rule length, L_R, less than 40 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion dependent upon the hull form, constructional arrangement and proposed loading.

2.1.3 Where the Rule length, L_R, of the craft exceeds 65 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

2.2 Bending strength

2.2.1 The effective geometric properties of the midship section are to be calculated directly from the dimensions of the section using only the effective material elements which contribute to the global longitudinal strength. For the purposes of this analysis an element may be a deck plating, longitudinal girder, inner bottom, etc., or other continuous member.

2.2.2 The distance of the neutral axis, y_{NA}, from the outer surface of the keel plate laminate may be determined from the following:

$$y_{NA} = \frac{\Sigma\,(E_i\,a_i\,x_i)}{\Sigma\,(E_i\,a_i)_H}\ \text{m}$$

2.2.3 The resultant compressive stress within an individual ply, *i*, may be determined from the following:

$$\sigma_{ci} = \frac{E_{ci}\,y_i\,M_R}{\Sigma\,(E_i\,I_i)_H} \times 10^{-3}\ \text{N/mm}^2$$

2.2.4 The resultant tensile stress within an individual ply, *i*, may be determined from the following:

$$\sigma_{ti} = \frac{E_{ti}\,y_i\,M_R}{\Sigma\,(E_i\,I_i)_H} \times 10^{-3}\ \text{N/mm}^2$$

2.2.5 The ultimate tensile and compressive strengths of the laminate or face reinforcement which form an element, may be determined from suitable tests or alternatively may be predicted using classical stress/strain relationships with due account being taken of the amounts of different materials and their associated strain rates to failure. In this respect materials which are incompatible in terms of their strain rates to failure are not to be mixed. Where materials are mixed the requirements of 2.2.6 for reserve factors are to be complied with when a first ply failure analysis is carried out.

2.2.6 The allowable tensile and compressive stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

2.3 Shear strength

2.3.1 The shear strength of the craft at any position along the length is to be examined. The shear stress, τ_H, is determined from the following:

$$\tau_H = \frac{Q_R}{A_\tau} \times 10^{-3}\ \text{N/mm}^2$$

where
A_τ = effective shear area of transverse section, in m^2, to be taken as the net sectional area of the side shell plating and the longitudinal bulkheads after deductions for openings, in m^2
Q_R is as defined in 1.2.1.

2.3.2 The allowable shear stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

2.4 Torsional strength

2.4.1 Torsional stresses are typically small for ordinary mono-hulls less than 65 m in Rule length, L_R, and can generally be ignored.

2.4.2 The calculation of torsional stresses and/or deflections may be required when considering craft with unusual form or proportions, or with large deck openings. In general, calculations may be required to be carried out using a direct calculation procedure. Such calculations are to be submitted in accordance with 1.5.

Section 3
Hull girder strength for multi-hull craft

3.1 Application

3.1.1 Except as otherwise specified within this Section, the global strength requirements for multi-hull craft are to comply with Section 2.

3.1.2 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 35 m, covering the range of load conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions and for any special mid-voyage conditions caused by changes in ballast distribution.

3.1.3 For craft of ordinary hull form with Rule length, L_R, less than 35 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion dependent upon the hull form, constructional arrangement and proposed loading.

3.1.4 Where the Rule length, L_R, of the craft exceeds 50 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

3.1.5 The strength deck plating in way of the cross-deck structure, the wet-deck plating, longitudinal bulkheads and girders, and other continuous members may be included in the determination of the midship section stiffness.

3.1.6 Special consideration will be given to the global strength requirements for craft with more than two hulls linked by cross-deck structure.

3.2 Hull longitudinal bending strength

3.2.1 The requirements of 2.2 are to be complied with, using the appropriate design bending moment applicable to multi-hull craft, as determined from Pt 5, Ch 5,5.

3.2.2 The allowable tensile and compressive stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

3.3 Hull shear strength

3.3.1 The requirements of 2.3 are to be complied with in so far as they are applicable.

3.3.2 The allowable shear stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

3.4 Torsional strength

3.4.1 At the discretion of LR or where a craft is of unusual form or novel construction, the torsional stress is to be determined by direct calculation methods using the twin hull torsional connecting moment as defined in Pt 5, Ch 5. Such calculations are to be submitted in accordance with 1.5.

3.5 Strength of cross-deck structures

3.5.1 Cross-deck structures are to have adequate transverse strength in relation to the design loads and moments. Generally the net areas with effective flange, after deductions of openings, are to be used for the calculations of the total stiffness of the longitudinal section of the cross-deck structures. The effective shear area of transverse strength members is the net web area after deduction of openings.

3.5.2 The twin hull transverse bending strength of the craft at any position along the length is to be examined.

3.5.3 The twin hull transverse bending stresses for both the compressive and tensile cases are to be determined by direct calculation methods, or on the basis of 2.2.3 and 2.2.4 respectively. The stresses are to be determined in conjunction with the twin hull transverse bending moment, M_R, as defined in Pt 5, Ch 5,5.

3.5.4 Due consideration is to be given to the increased bending moments which may arise due to local point loadings from pillars, fuel bunkers, heavy items of machinery, stores, etc.

3.5.5 The shear strength of the cross-deck structure is to be examined by applying the appropriate vertical shear force at the centreline of the cross-deck structure between the twin hulls. The shear stress, τ_V, is to be determined from:

$$\tau_V = \frac{Q_R}{A_\tau} \times 10^{-3} \text{ N/mm}^2$$

where

A_τ = the net cross sectional area of the primary transverse cross-deck structure, in m^2

Q_R is as defined in 1.2.1.

3.5.6 The allowable shear stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

3.6 Grillage structures

3.6.1 For complex girder systems, a complete structural analysis using numerical methods may be required to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended, *see also* Ch 3,4.15.

3.6.2 In general, the transverse and vertical girders, bottom and side structures, bridge structure, deck structures and any other parts of the craft which LR considers critical to the craft's structural integrity are to be included in the numerical modelling of the craft.

3.7 Analysis techniques

3.7.1 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

3.7.2 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

3.7.3 Analysis of the cross deck structures with regard to impact loads due to slamming may have to be carried out using advanced structural analysis techniques.

Section 1 General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of composite construction as defined in Ch 1,1.1.

1.2 General

1.2.1 The failure modes criteria contained within this Chapter are to be used in formulae from the preceding Chapters to determine the scantling requirements. In addition, they are to be used when direct calculations are proposed as an alternative.

1.3 Symbols and definitions

1.3.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate Section:

f_δ = span/deflection ratio.

1.4 Direct calculations

1.4.1 The requirements of this Section may be modified where direct calculation procedures are adopted to analyse the various failure modes.

1.5 Equivalents

1.5.1 Where direct calculations are proposed, the requirements of Pt 3, Ch 1,2 are to be complied with.

1.5.2 In addition, with the agreement of Lloyd's Register (hereinafter referred to as 'LR'), tests may be conducted to demonstrate the actual response of the structure and the results verified against the failure mode criteria in this Chapter.

Section 2 Deflection control

2.1 General

2.1.1 The requirements in respect of limiting deflection for both panels and stiffening members are given in this Section. These limits are generally based on a span/deflection ratio, f_δ, as given in Table 7.2.1, in consistent units.

Table 7.2.1 Limiting span/deflection ratio

Item	f_δ
Shell envelope:	
• sandwich construction	100
Bottom structure:	
• secondary stiffening	150
• primary girders and web frames	200
Side structure:	
• secondary stiffening	150
• primary girders and web frames	200
Main/strength deck structures:	
• sandwich construction	150
• secondary stiffening	200
• primary girders and web frames	250
• hatch covers	250
Superstructure/deckhouse laminates:	
(a) Generally: • sandwich construction	100
(b) Coachroof: • sandwich construction	150
(c) House top: • sandwich construction	100
(d) Lower/inner decks and house top subject to personnel loading:	
• sandwich construction	150
Superstructure/deckhouse stiffeners:	
(a) Generally: • secondary	100
• primary	150
(b) Coachroof: • secondary	150
• primary	200
(c) House top: • secondary	100
• primary	100
(d) Lower/inner decks and house top subject to personnel loading:	
• secondary members	150
• primary members	200
Deep tank structures:	
(a) Laminates: • sandwich construction	150
(b) Stiffeners: • secondary members	175
• primary members	200
Watertight bulkhead structures:	
(a) Laminates: • sandwich construction	100
(b) Stiffeners: • secondary members	125
• primary members	150
Multihull cross-deck structures:	
(a) Laminates: • sandwich construction	100
(b) Stiffeners: • secondary members	125
• primary members	150
Vehicle deck structures:	
(a) Laminates: • sandwich construction	150
(b) Stiffeners: • secondary members	200
• primary members	250
Helicopter/flight decks:	
(a) Laminates: • sandwich construction	150
(b) Stiffeners: • secondary members	200
• primary members	250
NOTE Where significant curvature exists over the span of the stiffener or breadth of the panel, the allowable deflections will be specially considered.	

Section 3
Stress control

3.1 General

3.1.1 The nominal limiting stress for panels and primary and secondary stiffening members, subject to local and global loading conditions, are given in this Section.

3.2 Tensile and compressive stress

3.2.1 The limiting tensile and compressive stress criteria values for local and global loading conditions are given in Tables 7.3.1 and 7.3.2 respectively. These values are expressed as a fraction of the ultimate tensile and compressive strength of the laminate at first ply failure.

3.3 Shear stress

3.3.1 The limiting shear stress criteria values for local and global loadings are given in Tables 7.3.1 and 7.3.2 respectively. These values are expressed as a fraction of the ultimate shear strength of the laminate.

3.4 Interlaminar shear stress

3.4.1 The interlaminar shear strength of the proposed laminate is to be demonstrated to be not less than 13,8 N/mm^2.

3.5 Core shear stress

3.5.1 In the core of all sandwich constructions the core shear stress is not to exceed 30 per cent of the ultimate core shear strength of the core material, *see also* Ch 3,1.13.9.

Table 7.3.1 Limiting stress criteria for local loading
(*see continuation*)

Item	Limiting stress fraction		
	Tensile	Compressive	Shear
Shell envelope:			
(a) Bottom shell laminate:			
• slamming zone	0,28	0,28	—
• elsewhere	0,25	0,25	—
(b) Side shell laminate:			
• slamming zone	0,33	0,33	—
• elsewhere	0,30	0,30	—
(c) Keel	0,25	0,25	—
Bottom structure:			
(a) Secondary stiffening:			
• slamming zone	0,33	0,33	0,33
• elsewhere	0,30	0,30	0,30
(b) Primary girders and web frames	0,33	0,33	0,33
(c) Engine girders	0,33	0,33	0,33
Side structure:			
(a) Secondary stiffening:			
• slamming zone	0,33	0,33	0,33
• elsewhere	0,30	0,30	0,30
(b) Primary girders and web frames	0,33	0,33	0,33
Main/strength deck laminate and stiffeners:			
(a) Laminate	0,30	0,30	—
(b) Secondary stiffening	0,30	0,30	0,30
(c) Primary girders and web frames	0,33	0,33	0,33
(d) Hatch covers	0,25	0,25	0,25
Superstructures/deckhouses:			
(a) Deckhouse front, 1st tier:			
• laminate	0,30	0,30	—
• stiffening	0,33	0,33	0,33
(b) Deckhouse front, upper tiers:			
• laminate	0,30	0,30	—
• stiffening	0,33	0,33	0,33
(c) Deckhouse, aft and sides:			
• laminate	0,30	0,30	—
• stiffening	0,33	0,33	0,33
(d) Coachroof:			
• laminate	0,30	0,30	—
• stiffening	0,33	0,33	0,33
(e) House top, not subject to personnel loading:			
• laminate	0,40	0,40	—
• stiffening	0,40	0,40	0,40
(f) Lower/inner decks and house top, subject to personnel loading:			
• laminate	0,33	0,33	—
• stiffening	0,30	0,30	0,30

Table 7.3.1 Limiting stress criteria for local loading
(*conclusion*)

Item	Limiting stress fraction		
	Tensile	Compressive	Shear
Bulkheads:			
(a) Collision bulkhead:			
• laminate	0,26	0,26	—
• secondary stiffening	0,32	0,32	0,32
• primary stiffening	0,32	0,32	0,32
(b) Watertight bulkhead:			
• laminate	0,33	0,33	—
• secondary stiffening	0,40	0,40	0,40
• primary stiffening	0,40	0,40	0,40
(c) Watertight bulkhead doors:			
• in collision bulkhead	0,25	0,25	—
• in other bulkheads	0,33	0,33	—
(d) Structure supporting watertight doors:			
• in collision bulkhead	0,25	0,25	0,25
• in other bulkheads	0,33	0,33	0,33
(e) Minor bulkheads:			
• laminate	0,50	0,50	—
• secondary stiffening	0,50	0,50	0,50
• primary stiffening	0,50	0,50	0,50
(f) Deep tank bulkheads:			
• laminate	0,25	0,25	—
• secondary stiffening	0,33	0,33	0,33
• primary stiffening	0,33	0,33	0,33
Multihull cross-deck structure:			
(a) Laminate:			
• slamming zone	0,33	0,33	—
• elsewhere	0,30	0,30	—
(b) Secondary stiffening:			
• slamming zone	0,33	0,33	0,33
• elsewhere	0,30	0,30	0,30
(c) Primary stiffening	0,33	0,33	0,33
Vehicle deck:			
(a) Laminate	0,25	0,25	—
(b) Secondary stiffening	0,33	0,33	0,33
(c) Primary stiffening	0,33	0,33	0,33
Helicopter/flight decks:			
(a) Normal usage:			
• laminate	0,25	0,25	—
• secondary stiffening	0,33	0,33	0,33
• primary stiffening	0,33	0,33	0,33
(b) Emergency landing:			
• laminate	0,33	0,33	—
• secondary stiffening	0,43	0,43	0,43
• primary stiffening	0,43	0,43	0,43

Table 7.3.2 Limiting stress criteria for global loading

Operational mode of craft	Limiting stress fraction			
	Tensile	Compressive	Shear (*see* Note 1)	Shear (*see* Note 2)
$\Gamma \geq 3{,}0$ or $\Delta \leq 0{,}04(L_R\, B)^{1,5}$	0,33	0,33	0,33	0,33
$\Gamma < 3{,}0$ and $\Delta > 0{,}04(L_R\, B)^{1,5}$	0,25	0,25	0,25	0,25

NOTES
1. Limiting stress fraction for the hull shear stress at any point along the craft length.
2. Limiting stress fraction for the vertical shear stress for the cross-deck structure.

Δ is the displacement as defined in Pt 5, Ch 2,2.
Γ is the Taylor Quotient as defined in Pt 5, Ch 2,2.1.16.
L_R and B are as defined in Pt 3, Ch 1,6.2.

■ *Section 4* Buckling control

4.1 General

4.1.1 The requirements in respect of the control of buckling of single skin and sandwich panels, including global buckling of structures, pillars and pillar bulkheads are given in this Section.

4.2 Single skin laminate

4.2.1 Where single skin laminate panels are subject to compressive loading likely to cause axial buckling, design calculations are to be submitted indicating the margin against failure.

4.3 Sandwich skin laminate

4.3.1 Where sandwich panel skin laminates are subject to compressive loading likely to cause axial buckling, design calculations are to be submitted indicating the margin against failure.

4.3.2 Where sandwich panels subject to compressive loading have skin thicknesses which are less than the minimum required by Ch 3,2.3, design calculations are to be submitted indicating the margin against failure due to wrinkling of the sandwich skin laminates.

4.3.3 Where production methods or the craft design gives rise to local distortion or irregularity of the sandwich, the designer is to make due allowance for the reduction in critical wrinkling stress.

4.4 Pillars and pillar bulkheads

4.4.1 In general, the requirements in respect of the control of buckling of pillars and pillar bulkheads are given in Ch 3,10.

■ *Section 5* Impact control

5.1 General

5.1.1 Skin thicknesses may be accepted which are below the stated Rule minima indicated throughout the Rules provided that acceptable stress levels are predicted for the in service condition and that equivalent impact strength can be demonstrated to the satisfaction of LR. In such cases due consideration is to be given to providing a satisfactory water barrier and ensuring suitability to resist abrasion, local point loadings, etc., *see* Ch 3,2.

5.2 Testing

5.2.1 All impact tests are to be comparative tests using the Rule basic laminate as the comparative standard. Original and tested samples of both the proposed laminate and the Rule comparison laminate are to be submitted for LR's consideration together with a detailed test report. Testing is to be carried out by the Builder and witnessed by the LR Surveyor or at an independent testing establishment, acceptable to LR. Comparison will be by visual inspection only and interpretation of the results will be at the sole discretion of LR.

■ *Section 6* Temperature control of cored sandwich structures

6.1 General

6.1.1 Where foam core materials are used in sandwich construction the properties at elevated temperature are to be considered. Where appropriate the mechanical properties are to be those at the maximum ambient temperature expected under normal operating conditions.

6.1.2 Alternatively other methods of controlling the temperature of the core may be considered, e.g. inserts, insulation.

6.2 Information required

6.2.1 The source of the mechanical properties data is to be shown on the Materials Data Sheet (Form 2075) when the plans are initially submitted for approval.

6.2.2 Test data is to be submitted for each grade of foam core in respect of:

- Core shear strength.
- Core shear modulus.
- Tensile strength
  (only for high density cores, i.e. > 100 kg/m^3).
- Tensile modulus
  (only for high density cores, i.e. > 100 kg/m^3).

6.3 Testing

6.3.1 Core materials are to be tested in accordance with Part 2.

6.4 National Authority requirements

6.4.1 National Authority requirements are to be complied with as applicable.

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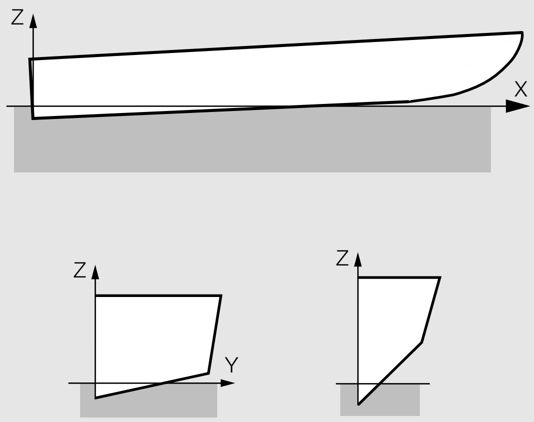
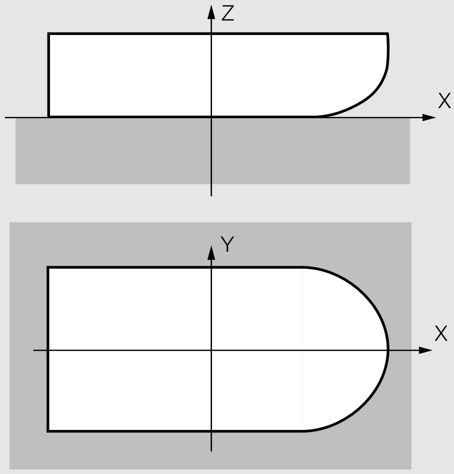
Lloyd's Register

DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

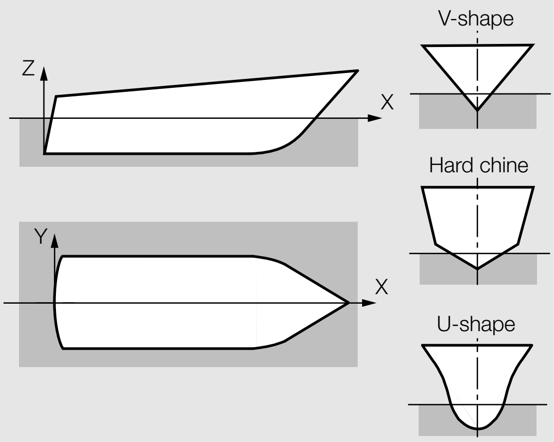
PLANING CRAFT



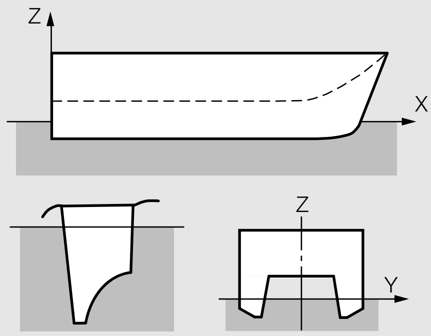
HOVERCRAFT



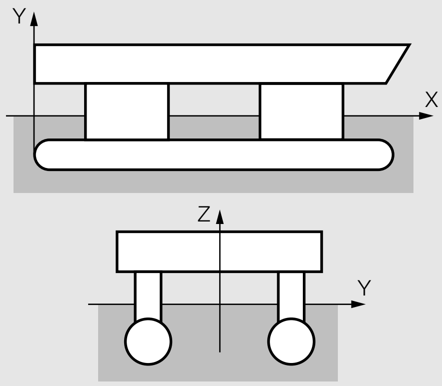
DISPLACEMENT CRAFT



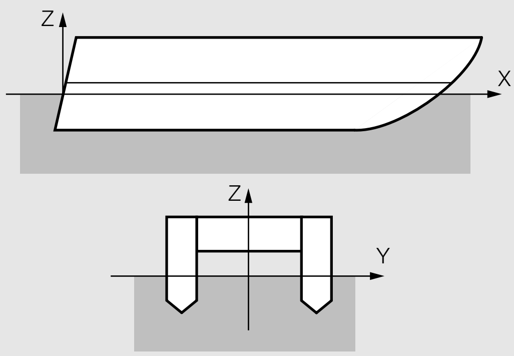
SURFACE EFFECT SHIP



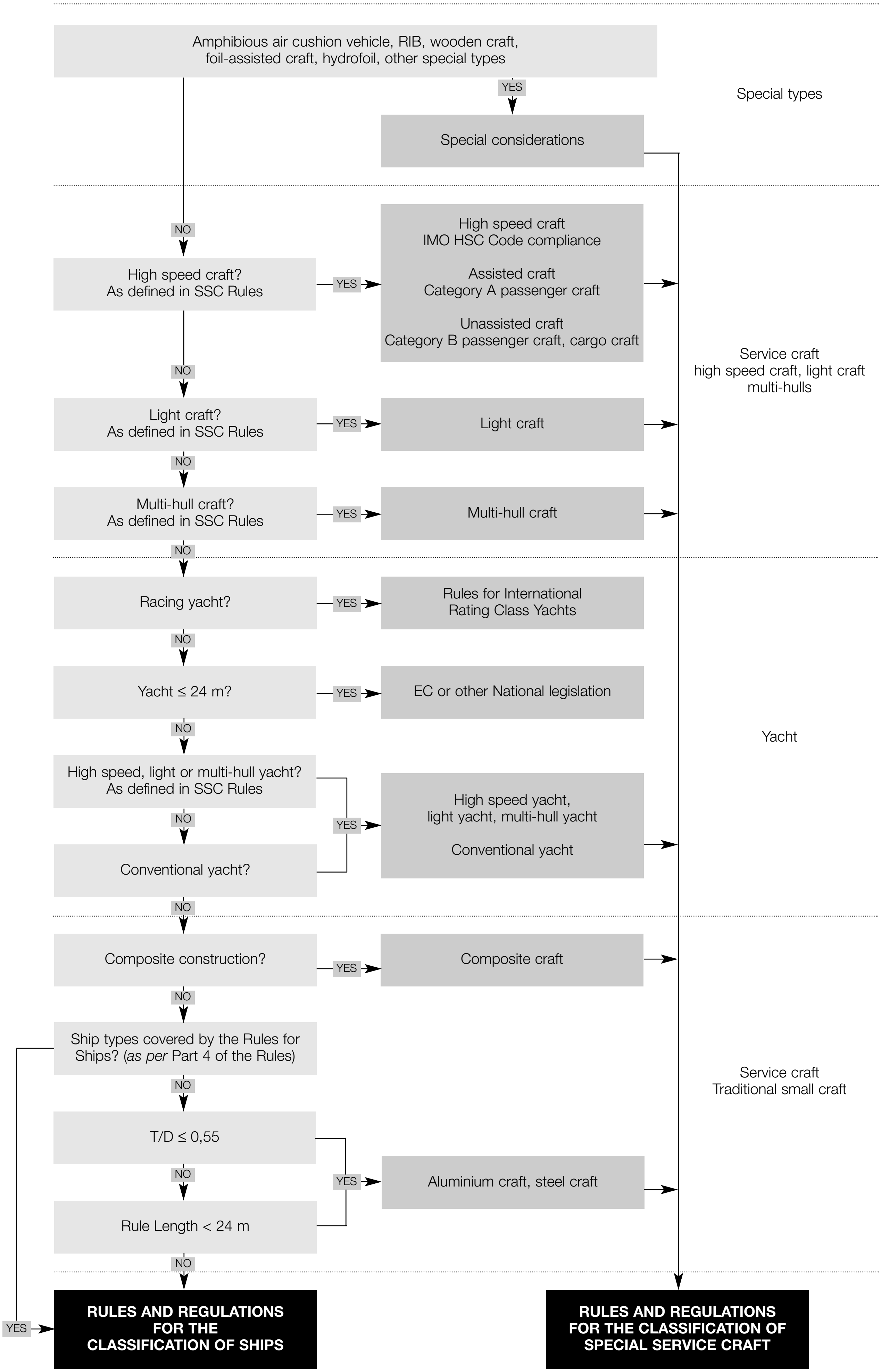
SMALL WATERPLANE AREA TWIN HULL (SWATH)



CATAMARAN



DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



RULES AND REGULATIONS FOR THE CLASSIFICATION OF SPECIAL SERVICE CRAFT

GENERAL REQUIREMENTS FOR MACHINERY

JULY 2008

VOLUME 7

PART 9

Lloyd's Register

Chapter Contents

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Part 9

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 Parts 9 to 16 apply to the design, construction, installation and testing of:

- Main propulsion machinery systems
- Essential auxiliary machinery systems having powers in excess of 110 kW
- Steering and manoeuvring systems

together with their associated equipment, pressure plant, piping systems, control engineering and electrical engineering systems for the craft types stated in Pt 1, Ch 2,1.

1.1.2 The Rules incorporate those requirements of the *International Convention for the Safety of Life at Sea, 1974* as amended (SOLAS 74) Chapter X – Safety Measures for High Speed Craft (International Code of Safety for High Speed Craft) hereinafter referred to as the HSC code, as applicable to the classification of such craft.

1.1.3 Requirements for craft which are not required to comply with the IMO Code for High Speed Craft are given at the end of each Chapter. Requirements for service craft, yachts of 24 m or greater and other craft types have been included in these alternative requirements. For the purposes of Parts 9 to 16, small craft are service craft of less than 24 m in length.

1.1.4 Special requirements are included for main and auxiliary machinery, pumping and piping, electrical and control engineering and fire extinction for yachts that are 500 gt or more.

1.1.5 These Rules are applicable to machinery systems burning distillate fuels which do not require to be heated.

1.2 General

1.2.1 The units and formulae used in the Rules are in SI Units.

1.2.2 It is the responsibility of the Shipbuilder as main contractor to ensure that the information required is prepared and submitted.

1.2.3 Where the craft is defined as a Passenger (B) Craft (*see* Pt 1, Ch 2,3), sufficient redundancy is to be provided such that in the event of damage to any part of a main propulsion drive system, the craft is able to maintain sufficient seaway.

1.2.4 Sufficient astern power is to be provided to maintain control of the craft in all normal circumstances.

1.2.5 The main propulsion machinery will be approved for the maximum continuous power, and associated shaft speed, required to achieve the maximum craft velocity at the certified maximum operational weight in smooth water.

1.2.6 Main propulsion machinery will be considered for operation at a higher power rating than the classification rating for short time intervals (referred to as short term high power operation) in conjunction with the intended operation service profile.

1.2.7 Provision shall be made to facilitate cleaning, inspection and mantenance of main propulsion and auxiliary machinery including boilers and pressure vessels.

1.3 Fuel flash point

1.3.1 The flash point (closed cup test) of oil fuel is in general to be not less than 60°C. For emergency generator engines a flash point of not less than 43°C is permissible.

1.3.2 Oil fuel with a flash point lower than 60°C may be used where it can be shown that the temperature of the oil fuel will always be not less than 10°C below its flash point.

1.3.3 The use of fuel with a flash point below 43°C is not recommended. However, fuel with a lower flash point , but not lower than 35°C, may be used in gas turbines only, subject to compliance with the provisions in Section 4.

1.4 Exhaust

1.4.1 Where the surface temperature of the exhaust pipes and silencer may exceed 220ºC, they are to be water cooled or efficiently lagged to minimize the risk of fire and to prevent damage by heat. Where lagging covering the exhaust piping system including flanges is oil-absorbing or may permit penetration of oil, the lagging is to be encased in sheet metal or equivalent. In locations where the Surveyor is satisfied that oil impingement could not occur, the lagging need not be encased.

1.5 Bearings

1.5.1 Roller element bearings are to have an L10 design life of at least 30 000 hours, based upon the design operating conditions, including short term high power operation. An L10 design life of less than 30 000 hours would be accepted, provided it is proposed in conjunction with the manufacturer's design/maintenance manual.

1.6 Vibration of shaft systems

1.6.1 The Shipbuilders are to ensure that the systems are free from excessive vibrations, excessive bearing reactions and excessive bending moments under all design operating conditions.

1.6.2 Where changes are subsequently made to a dynamic system which has been approved by Lloyd's Register (hereinafter referred to as 'LR'), e.g. machining a shaft, fitting a propeller of a different design to the working propeller or fitting a different flexible coupling, full details of the changes are to be advised. Revised calculations may be required to be submitted.

1.6.3 Where there is experience of previous similar systems which have been approved, full details of these installations may be submitted for consideration in lieu of calculations.

1.7 Alternative system of survey

1.7.1 Where items of machinery are manufactured as individual or series produced units, LR will give consideration to the adoption of a survey procedure based upon an approved quality assurance system to ISO 9001 (or equivalent) utilizing regular and systematic audits of the approved manufacturing and quality control processes and procedures as an alternative to the direct survey of individual components.

■ *Section 2* Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of plans, information and specifications as listed are to be submitted before commencement of manufacture.

2.2 Plans

2.2.1 Plans are to indicate clearly the scantlings and materials of construction. Any design alteration to the plan is to be resubmitted for approval, indicating clearly the alteration.

2.2.2 Individual Chapters also list plans to be submitted for specific machinery systems or components.

2.2.3 Where machinery system components have been approved under LR's Type Approval System or Machinery General Design Appraisal for the proposed design conditions or service, plans of the components will not be required to be submitted for individual newbuildings. Full details of the components are to be advised.

2.2.4 Plans showing the arrangement of resiliently mounted machinery are to indicate the number, position, type, and design of mounts.

2.2.5 The plans of arrangement of resin chocks for machinery requiring accurate alignment are to be submitted.

2.3 Calculations and specifications

2.3.1 Relevant data covering the following topics is to be submitted.

2.3.2 **Service Profile.** The machinery power/speed operational envelope indicating all the intended operational points applicable to the class notation, and any short term high power operation.

2.3.3 **Classification rating**:

(a) The following operational parameters are to be taken, using the design conditions for the intended Class Notation:
- Total barometric pressure, in bar.
- Temperature of engine room, or suction air, in °C.
- The relative humidity, in per cent.
- Temperature of sea water, or charge air coolant inlet, in °C.

(b) For unrestricted service, the following operational parameters ambient reference conditions are to be taken:
- Total barometric pressure, at 1000 mb.
- Temperature of engine room or suction air, at 45°C.
- Relative humidity, at 60 per cent.
- Temperature of sea water or charge air coolant inlet, at 32°C.

2.3.4 **Short term high power operation**. Where the propulsion machinery is being considered for short term high power operation, full details of the power, speed and time intervals together with fatigue endurance calculations, and documentary evidence indicating the suitability of the component design under these conditions and for the intended class notation are required. The following are to be considered; prime mover, gearbox, flexible coupling, vibration dampers, shafting and propeller:

(a) The accrued number of load cycles and the percentage component overload are to be those recommended by the designers.

(b) Excessive overload may require the interval between surveys to be reduced.

(c) Machinery is to be maintained in accordance with the manufacturers' requirements.

2.3.5 **Damper and Flexible Coupling characteristics**. Documentary evidence that the characteristics have been verified.

2.3.6 **Machinery Fastening**.

(a) Documentary evidence and calculations indicating that machinery is securely mounted for the accelerations to be expected during service.

(b) Calculations that mountings of large masses such as main engines, auxiliary engines, lift fans and electrical equipment can withstand the design collision acceleration according to 5.2.1 without fracturing.

(c) Natural frequency calculation of resilient mounted machinery.

(d) For non-metallic machinery chocks:

(i) Resin type.

(ii) The effective area and minimum thickness of the chocks.

(iii) The total deadweight loading of machinery.

(iv) The thrust load, where applicable, that will be applied to the chocked item.

(v) The loading to be applied to the holding-down bolts.

(vi) The material of the holding-down bolts.

(vii) The number, thread size, and waisted shank diameter (where applicable) of the holding-down bolts.

2.3.7 **Manuals**. The operation and maintenance manuals.

2.3.8 **Failure Mode and Effect Analysis**. Where required for high speed craft, an FMEA is to be carried out covering the following systems:

(a) Main and auxiliary machinery systems, and their controls.

(b) Steering systems.

(c) Electrical systems.

2.3.9 **Fatigue Strength Analysis**. Where undertaken as an alternative to the requirements of the individual Chapters, fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads based on a suitable fatigue failure criteria. The effects of stress concentrations, material properties and operating environment are to be taken into account.

■ *Section 3* Certification of materials

3.1 Materials of construction

3.1.1 Materials used in the construction are to be in accordance with, or shown to be equivalent to *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Details of all materials included and not included in the Rules for Materials are to be forwarded as soon as possible (preferably at the design concept stage) and before commencement of manufacture.

■ *Section 4* Operating conditions

4.1 Machinery control

4.1.1 The design and arrangement is to be such that the machinery can be started and controlled on board, without external aid, so that the operating conditions for which the craft is classed, can be maintained.

4.2 Inclinations of the craft

4.2.1 The main and auxiliary machinery is to be designed and installed such that it operates satisfactorily under the conditions as shown in Table 1.4.1.

Table 1.4.1 Inclinations

Installations, components	Angle of inclination, degrees, *see* Note 1			
	Athwartship		Fore-and-aft	
	Static	Dynamic	Static	Dynamic
Main and auxiliary machinery essential to the propulsion and safety of the craft	15	22,5	5 (*see* Note 2)	7,5
Emergency machinery and equipment fitted in accordance with Statutory Requirements	22,5	22,5	10	10

NOTES
1. Athwartships and fore-and-aft inclination may occur simultaneously.
2. Where the length of the craft exceeds 100 m, the fore-and-aft static angle of inclination may be taken as:

$$\frac{500}{L_{WL}} \text{ degrees}$$

where
L_{WL} = craft waterline length, in metres

4.2.2 The arrangements for lubricating bearings and for draining crankcase and other oil sumps of main and auxiliary engines, gearcases, electric generators, motors, and other running machinery are to be so designed that lubrication will remain efficient with the craft inclined under the conditions as shown in Table 1.4.1.

4.2.3 Deviations from these conditions may be accepted taking into consideration type and size of the craft and the class notation. The Shipbuilder is to ensure that the main and auxiliary machinery is capable of operating at the proposed angles of inclination.

4.3 Power ratings

4.3.1 In the Chapters where the dimensions of any particular component are determined from shaft power, P, in kW (H, in shp), and revolutions per minute, R, the values to be used are to be derived from the following:

- For main propelling machinery, the maximum shaft power and corresponding revolutions per minute giving the maximum torque for which the machinery is to be classed.
- For auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute which will be used in service.

4.4 Ambient operating conditions

4.4.1 Main and essential auxiliary machinery and equipment is to be capable of operating satisfactorily under the conditions shown in Table 1.4.2.

Table 1.4.2 Ambient operating conditions

Air		
Installations, Components	Location, arrangement	Temperature range (°C)
Machinery and electrical installations	In enclosed spaces	0 to +45, *see* Note 1
	On machinery components, boilers. In spaces subject to higher and lower temperatures	According to specific local conditions, *see* Note 2
	On the open deck	–25 to +45, *see* Note 1
Water		
Coolant		Temperature (°C)
Sea-water or charge air coolant inlet to charge air cooler		-2 to +32, *see* Notes 1 and 3

NOTES
1. For ships intended to be classed for restricted service, a deviation from the temperatures stated may be considered.
2. Details of local environmental conditions are stated in Annex B of IEC 60092: *Electrical installations in ships – Part 101: Definitions and general requirements.*
3. Charge air cooling arrangements utilising re-circulated cooling to maintain temperatures in a different range are accepted where the machinery and equipment operation is not degraded with a primary supply of cooling in the temperature range stated in this Table.

4.4.2 Where it is intended to allow for operation in ambient temperatures outside those shown in Table 1.4.2, the permissible temperatures and associated periods of time are to be specified and details are to be submitted for consideration. Propelling and essential auxiliary machinery, *see* Pt 1, Ch 2, 3.10.1, is to retain a continuous level of functional capability under these conditions and any level of degraded performance is to be defined. Operation under these circumstances is not to be the cause of damage to equipment in the system and is additionally to be acceptable to the National Authority of the country in which the craft is to be registered

■ *Section 5* Securing of machinery

5.1 Fastenings

5.1.1 Bedplates, thrust seatings and other fastenings are to be of robust construction. The machinery is to be securely fixed to the craft's structure, such that the arrangement is sufficient to restrain the dynamic forces arising from vertical and horizontal acceleration appropriate to the intended service.

5.2 Collision load

5.2.1 Unless an accurate analysis of the collision load is submitted and found acceptable by LR, the collision load is to be determined from:

$$g(\text{collision}) = 1{,}2\,\frac{P_{coll}}{\Delta g}$$

where the load P_{coll} is taken as the lesser of:

$P_{coll} = 460\,(M\,C_L)^{2/3}\quad(E\,C_H)^{1/3}$ kN

$P_{coll} = 9000\,M\,C_L\;[C_H\,(T + 2)]^{1/2}$ kN

where

C_H = a factor given in Table 1.5.1

$C_L = \dfrac{(165 + L_{WL})}{245}\left(\dfrac{L_{WL}}{80}\right)^{0,4}$

D = craft depth, in metres, from the underside of keel amidships to the top of effective hull girder

E = $0{,}5\,\Delta\,V^2$ kNm

H_T = minimum height, in metres, from tunnel or wet-deck bottom to the top of effective hull girder for catamarans and surface effect ships
= D for air cushion vehicles

L_{WL} = craft waterline length, in metres

M = 1,3 for high tensile steel
= 1,0 for aluminium alloy
= 0,95 for mild steel
= 0,8 for fibre reinforced plastics

T = buoyancy tank clearance to skirt tip, in metres, (negative) for ACVs
= lifted clearance from keel to water surface, in metres, (negative) for hydrofoils
= craft draught to the underside of keel amidships, in metres, for all other craft

V = operational speed of craft, in m/s

g = gravitational acceleration = 9,806 m/s^2
Δ = craft displacement, to be taken as the mean of the lightweight and maximum operational weight, in tonnes.

Table 1.5.1 Factor C_H

Factor, C_H	Catamarans, SES	Mono-hulls, H'Foils	ACVs
C_H	$\dfrac{T + 2 + f\,(D/2)}{2D}$	$\dfrac{T + 2 + f\,(D/2)}{2D}$	$\dfrac{f}{4}$
where f = 0 for f = 1 for f = 2 for	 $T + 2 < D - H_T$ $D > T + 2 \geq D - H_T$ $T + 2 \geq DM$	 $T + 2 < D$ $T + 2 \geq D$ —	 — $H_T > 2$ $H_T \leq 2$

5.3 Resilient mounts

5.3.1 Creep of rubber mounts and the effects on the alignment are also to be considered.

5.3.2 Shafting, piping connections and electrical cable connections are to be provided with sufficient flexibility to accommodate such movements. Particular attention should be paid to exhaust bellows and the effectiveness of flexible couplings.

5.3.3 Limit stops are to be fitted as necessary to ensure that manufacturers' limits are not exceeded. Suitable means are to be provided to accommodate propeller thrust.

5.3.4 Mounts are to be shielded from the possible detrimental effects of oil.

5.4 Machinery mounted on resin chocks

5.4.1 These Rules relate to the application of synthetic resin compounds as materials for chocks under machinery components where accurate alignments are important, e.g. main engine, gearbox and auxiliary installations where the engine and generator do not share a common baseplate.

5.4.2 Resin compounds used in these applications are to be of a type accepted by LR.

5.4.3 The use of resin for chocking gas turbine casings or similar high temperature applications will not be considered.

■ *Section 6* Requirements for craft which are not required to comply with the HSC Code

6.1 Plans and particulars

6.1.1 At least three copies of the following plans are to be submitted for approval at the earliest opportunity:

- Crankshaft including details of the material specification.
- Gearing including details of the material specification.
- Arrangement and details of the propulsion shafting, couplings and bearing disposition, etc.
- Propeller where the diameter exceeds 1 m.
- Diagrammatic arrangements of the exhaust systems indicating the materials, methods of cooling, and if water spray is injected, the method of draining.
- Starting air system and receivers.
- Diagrammatic arrangements of pumping and piping systems including the air and sounding pipes for the tanks.
- Diagrammatic arrangements of bilge and fire water pumps and piping for craft having a Rules length of 12 m and over and which are subdivided into watertight compartments.
- Diagrammatic arrangement of oil fuel piping.
- Construction arrangements of separate oil fuel tanks having a capacity exceeding 250 litres.
- Electrical equipment as detailed in Pt 16, Ch 2.
- Steering gear machinery and hydraulic circuit diagram if applicable.
- Fire extinction equipment as detailed in Part 17.
- Safety plan showing the position of all fire prevention controls, fixed and loose equipment and portable extinguishers, *see* Pt 17, Ch 1 to 4.
- Control circuits and alarm points as detailed in Pt 16, Ch 1.

6.1.2 The following particulars are to be submitted with the plans of crankshaft, gearbox or shafting as applicable:

- Name of manufacturer.
- Type designation.
- Particulars of engine cycle.
- Number of cylinders and vee angle where applicable.
- Maximum combustion pressure and mean indicated pressure.
- Span of bearings adjacent to a crank measured from centreline of the bearing to the centreline of the adjacent bearing.
- Proposed shaft power (kW) and revolutions per minute of the engine at each operating condition.
- Gear box reduction ratio.
- For engines over 500 kW, *see* Pt 10, Ch 1,3.

6.1.3 Where machinery system components or equipment have been approved under LR's Type Approval System or Machinery General Design Appraisal for the proposed design conditions or intended service, full details of the components should be advised to enable the validity of the approval to be checked. In cases where valid approvals are confirmed, plans are not required to be submitted for approval for individual craft.

6.2 Calculations

6.2.1 Design calculations are to be submitted for the following systems and conditions:

(a) Direct calculation for design strength of machinery supports, such as engine mountings, on craft subjected to high accelerations, *see* Section 5.

(b) Calculations of torsional vibrations for main engines where the power exceeds 500 kW and for auxiliary engines for essential services where the power exceeds 110 kW.

6.3 Certification of materials

6.3.1 The requirements of 3.1 apply to all types of craft.

6.3.2 Where no provision is made in these Rules, materials may be accepted provided that they comply with an approved specification and such tests as may be considered necessary by the Surveyor.

6.3.3 The requirements for materials for machinery components are indicated in the relevant Part or Chapter of the Rules.

6.4 Operating conditions

6.4.1 The requirements of 4.2 do not apply to yachts or service craft less than 24 m.

6.4.2 For patrol craft and high speed craft of 24 m or greater, the main and auxiliary machinery is to be designed to operate under the conditions defined in Sections 4 and 5.

6.4.3 If operation under the required accelerations cannot be demonstrated on trials, alternative documentary evidence is to be presented to confirm that the machinery is capable of operating under such conditions.

6.4.4 Additional trials or conditions may be imposed to prove the machinery as considered necessary.

6.5 Securing of machinery

6.5.1 The requirements of 5.1, 5.3 and 5.4 apply.

6.5.2 Engines are to be installed so as to permit easy access to fittings, such as lubricating oil connections, bilge suctions and sea cocks.

6.5.3 Where the hull is constructed of FRP, wood or composites, and the hull surfaces are not adequately protected against oil contamination, drip trays are to be fitted under those parts of the engine and gearbox where leakage of oil fuel or lubricating oil might occur. Means are to be provided for removing any leakage easily.

6.5.4 Where resilient mounts are fitted, the name of the manufacturer and details of the type of mounting are to be indicated on the plan of the shafting.

6.5.5 Where inclinations beyond those defined in 4.2 might be experienced, such as yacht roll over, means are to be provided to prevent machinery becoming dislodged.

6.5.6 Satisfactory arrangements are to be made to transmit the propulsion thrust into the craft structure.

6.6 Ventilation of machinery spaces

6.6.1 For yachts and service craft of less than 24 m the ventilation of the machinery space is to be adequate for all conditions of the operation of the machinery and in no case is to be less than that required by the engine manufacturer.

6.6.2 The engine compartment is to be provided with inlet and outlet ventilating ducts. One or more inlet ducts are to extend down to a suitable low level.

6.6.3 Outlet ducts are to be connected near or at the top of the compartment and are to be arranged for natural or mechanical extraction as necessary.

6.6.4 Consideration will be given to equivalent alternative arrangements provided full details are submitted before construction is commenced.

Surveys During Construction, Installation and Sea Trials

Section

■ *Section 1* General requirements

1.1 Surveys during construction

1.1.1 Machinery is to be surveyed at the manufacturer's works from the commencement of work until the final test under working conditions. The Surveyors are to be satisfied that the materials, workmanship and arrangements are satisfactory and in accordance with the Rules.

1.1.2 Lloyd's Register's (hereinafter referred to as LR) requirements for the conditions of manufacture, survey and certification of materials used for the production of forged steel and castings used in the production of components are given in *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.2 Miscellaneous surveys

1.2.1 Resilient mounts are to be installed under survey and the machinery tested under full working conditions.

1.2.2 Alignment of machinery is to be checked after the first six months of operation.

■ *Section 2* Diesel engines

2.1 Construction and welding

2.1.1 Where engine structures are fabricated, assembly is to be carried out to an approved welding and stress relief heat treatment procedure.

2.1.2 On completion of welding and stress relief heat treatment, welds are to be examined. Welds in transverse girder assemblies are to be crack detected by an approved method. Other joints are to be similarly tested if required by the Surveyors.

2.1.3 Forgings and castings are to be examined at the manufacturer's works.

2.2 Hydraulic testing

2.2.1 Items are to be tested by hydraulic pressure as indicated in Table 2.2.1.

2.3 Non-destructive testing

2.3.1 Non-destructive tests of components are to be carried out to an approved procedure, *see also* Pt 10, Ch 1,3.1.

2.4 Engine type testing

2.4.1 New engine types or developments of existing types are to be subjected to an agreed programme of type testing to complement the design appraisal and review of documentation. The programme will need to include short term high power operation where applicable.

2.4.2 Guidelines for type testing of engines will be supplied on application.

2.4.3 An engine type is defined in terms of:
- Basic engine data, e.g. bore, stroke.
- Working cycle; 2 stroke, 4 stroke.
- Cylinder arrangement; in-line, vee.
- Cylinder rating.
- Fuel supply, e.g. direct or indirect injection.
- Gas exchange; natural aspiration, pressure charging arrangement.

2.4.4 Where an engine type has subsequently proved satisfactory in service with a number of applications a maximum uprating of 10 per cent may be considered without a further complete type test.

2.4.5 A type test will be considered to cover engines of a given design for a range of cylinder numbers in a given cylinder arrangement.

Table 2.2.1 Test pressures

Item	Test pressure
Fuel injection system: Pump body, pressure side; Valve; Pipe	The lesser of 1,5p or p + 295 bar
Cylinder cover, cooling space Cylinder liner, over the whole length of cooling space Piston crown, cooling space (where piston rod seals cooling space, test after assembly)	7,0 bar
Cylinder jacket, cooling space Exhaust valve, cooling space Turbo-charger, cooling space Exhaust pipe, cooling space Coolers, each side Engine driven pumps (oil, water, fuel, bilge)	The greater of 4,0 bar or 1,5p
Air compressor, including cylinders, covers, intercoolers and aftercoolers	Air side: 1,5p Water side: The greater of 4,0 bar or 1,5p
Scavenge pump cylinder	4,0 bar

NOTES
1. p is the maximum working pressure, in bar, in the item concerned.
2. Fuel pumps of the jerk or timed pump system are not included.
3. Turbo-charger air coolers need only be tested on the water side.
4. For forged steel cylinder covers alternative testing methods will be specially considered.

■ *Section 3* Turbo-chargers

3.1 Type testing

3.1.1 A type test is to consist of a hot gas running test of at least one hour duration at the maximum permissible speed and maximum permissible temperature. Following the test the turbo-charger is to be completely dismantled for examination of all parts.

3.1.2 Alternative arrangements will be considered.

3.2 Dynamic balancing

3.2.1 All rotors are to be dynamically balanced on final assembly to the Surveyor's satisfaction.

3.3 Overspeed tests

3.3.1 All fully bladed rotor sections and impeller/inducer wheels are to be overspeed tested for three minutes at either 20 per cent above the maximum permissible speed at room temperature or 10 per cent above the maximum permissible speed at the normal working temperature.

3.4 Mechanical running tests

3.4.1 Turbo-chargers are to be given a mechanical running test of 20 minutes duration at the maximum permissible speed.

3.4.2 Upon application, with details of an historical audit covering previous testing of turbo-chargers manufactured under an approved quality assurance scheme, consideration will be given to confining the test to a representative sample of turbo-chargers.

■ *Section 4* Gas turbines

4.1 Dynamic balancing

4.1.1 All rotors as finished-bladed and complete with half-coupling are to be dynamically balanced in accordance with the manufacturer's specification in a machine of sensitivity appropriate to the size of rotor.

4.2 Hydraulic testing

4.2.1 All casings are to be tested to a hydraulic pressure equal to 1,5 times the highest pressure in the casing during normal operation, or 1,5 times the pressure during starting, whichever is the higher. For test purposes, if necessary, the casings may be subdivided with temporary diaphragms for distribution of test pressure.

4.2.2 Where hydraulic tests cannot be carried out on the casing, alternative proposals will be considered.

4.2.3 Intercoolers and heat exchangers are to be tested to 1,5 times the maximum working pressure on each side separately.

4.3 Overspeed tests

4.3.1 Before installation, the gas turbine is to be tested for five minutes at five per cent above the nominal setting of the overspeed protective device, or 15 per cent above the maximum design speed, whichever is the higher.

4.3.2 Where it is impracticable to overspeed the complete installation, each rotor, completely bladed and with all relevant parts such as half-couplings, is to be overspeed-tested individually at the appropriate speed.

■ *Section 5* Gearing

5.1 Construction and welding

5.1.1 Where castings are used for wheel centres, any radial slots in the periphery are to be fitted with permanent chocks before shrinking-on the rim.

5.1.2 Where welding is employed in the construction of wheels and gearcases, the welding procedure is to be approved before work is commenced. For this purpose, welding procedure approval tests are to be carried out with satisfactory results. Such tests are to be representative of the joint configuration and materials. All welds are to have a satisfactory surface finish and contour. Magnetic particle or liquid penetrant examination of all important welded joints is to be carried out.

5.1.3 Welded constructions are to be stress relief heat treated on completion of welding.

5.1.4 Bolted attachments within the gear case are to be secured by locking wire or equivalent means.

5.2 Accuracy of gear cutting

5.2.1 The machining accuracy (Q grade) of pinions and wheels is to be demonstrated. For this purpose records of measurements are to be available for review.

5.3 Non-destructive testing

5.3.1 Magnetic particle or liquid penetrant testing is to be carried out on the teeth of all surface hardened forgings. This examination may also be requested on the finished machined teeth of through hardened gear forgings.

5.3.2 The manufacturer is to carry out an ultrasonic examination of all forgings where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm, and is to provide LR with a signed statement that such inspection has not revealed any significant internal defects.

5.3.3 On gear forgings where the teeth have been surface hardened, additional test pieces may be required to be processed with the forgings and subsequently sectioned to determine the depth of the hardened zone. These tests are to be carried out at the discretion of the Surveyor, and for induction or carburised gearing the depth of the hardened zone is to be in accordance with the approved specification. For nitrided gearing, the full depth of the hardened zone, i.e. depth to core hardness, is to be not less than 0,5 mm and the hardness at a depth of 0,25 mm is to be not less than 500 Hv.

5.4 Dynamic balancing

5.4.1 All rotating elements such as pinion and wheel shaft assemblies and coupling parts, are to be appropriately balanced.

5.4.2 The permissible residual unbalance, U, is defined as follows:

$$U = \frac{60m}{R} \times 10^3 \text{ g mm} \quad \text{for } R \leq 3000$$

$$U = \frac{24m}{R} \times 10^3 \text{ g mm} \quad \text{for } R > 3000$$

where
m = mass of rotating element, in kg
R = maximum service rev/min of the rotating element.

5.4.3 Where the size or geometry of a rotating element precludes measurement of the residual unbalance a full speed running test of the assembled gear unit at the manufacturer's works will normally be required to demonstrate satisfactory operation.

5.5 Meshing tests

5.5.1 Initially, meshing gears are to be carefully matched on the basis of the accuracy measurements taken. The alignment is to be demonstrated in the workshop by meshing in the gearbox without oil clearance in the bearings. Meshing is to be carried out with the gears locating in their light load positions and a load sufficient to overcome pinion weight and axial movement is to be imposed.

5.5.2 The gears are to be suitably coated to demonstrate the contact marking. The thickness of the coating to determine the contact marking is not to exceed 0,005 mm. The marking is to reflect the accuracy grade specified and end relief, crowning or helix correction, where these have been applied.

5.5.3 For gears without crowning or helix correction the marking is to be not less than shown in Table 2.5.1.

5.5.4 Where allowance has been given for end relief, crowning or helix correction, the normal shop meshing tests are to be supplemented by tooth alignment traces or other approved means to demonstrate the effectiveness of such modifications.

Table 2.5.1 No load tooth contact marking

ISO accuracy grade	Contact marking area
$Q \le 5$ $Q \ge 6$	50% b x 40% h_W + 40% b x 20% h_W 35% b x 40% h_W + 35% b x 20% h_W

NOTES
1. Where b is the face width and h_W is the working tooth depth.
2. For spur gears, the values of h_W should be increased by a further 10%.

5.5.5 For gears with crowning or helix correction, the marking is to correspond to the designed no load contact pattern.

5.5.6 A permanent record is to be made of the meshing contact for the purpose of checking the alignment when installed on board the craft.

5.5.7 The full load tooth contact marking is to be not less than shown in Table 2.5.2.

Table 2.5.2 Full load tooth contact marking

ISO accuracy grade	Contact marking area
$Q \le 5$ $Q \ge 6$	60% b x 70% h_W + 30% b x 50% h_W 45% b x 60% h_W + 35% b x 40% h_W

NOTES
1. Where b is the face width and h_W is the working tooth depth.
2. For spur gears, the values of h_W should be increased by a further 10%.

5.5.8 Where, due to the compactness of the gear unit, meshing tests of individual units cannot be verified visually, consideration may be given to the gear manufacturer providing suitable evidence that the design meshing condition has been attained on units of the same design.

5.5.9 The normal backlash between any pair of gears should not be less than:

$$\frac{a\,\alpha_n}{90000} + 0{,}1 \text{ mm}$$

where

α_n = normal pressure angle, in degrees

a = centre distance, in mm.

■ *Section 6* **Shafting systems**

6.1 Construction and installation

6.1.1 Boring of the sternframe, fitting of the sterntube and bearings and aligning the shafting are to be carried out to a formal traceable procedure.

6.1.2 Before boring the sternframe the structure should be generally complete to the upper deck and to the engine-room forward bulkhead.

■ *Section 7* **Propellers**

7.1 Construction and welding

7.1.1 Castings are to be examined at the manufacturer's works.

7.1.2 All finished propellers are to be examined for material defects and finish, and measured for dimensional accuracy of diameter and pitch. Propeller repairs by welding, where proposed, are to be in accordance with the requirements of Ch 9,1 of the Rules for Materials.

7.2 Shop tests of keyless propellers

7.2.1 The bedding of the propeller with the shaft is to be demonstrated. Sufficient time is to be allowed for the temperature of the components to equalize before bedding. Alternative means for demonstrating the bedding of the propeller will be considered.

7.2.2 Means are to be provided to indicate the relative axial position of the propeller boss on the shaft taper.

7.3 Shop tests of controllable pitch propellers

7.3.1 The components of controllable pitch propellers are also subject to material tests, as in the case of solid propellers.

7.3.2 Examination of all the major components including dimensional checks, hydraulic pressure testing of the hub and cone assembly and the oil distribution box, where fitted, together with a full shop trial of the completed controllable pitch propeller assembly, is to be carried out.

7.4 Final fitting of keyless propellers

7.4.1 After verifying that the propeller and shaft are at the same temperature and the mating surfaces are clean and free from oil or grease, the propeller is to be fitted on the shaft under survey. The propeller nut is to be securely locked to the shaft.

7.4.2 Permanent reference marks are to be made on the propeller boss nut and shaft to indicate angular and axial positioning of the propeller. Care is to be taken in marking the inboard end of the shaft taper to minimize stress raising effects.

7.4.3 The outside of the propeller boss is to be hard stamped with the following details:

- For oil injection method of fitting, the start point load, in Newtons, and the axial pull-up at 0°C and 35°C, in mm.
- For the dry fitting method, the push-up load at 0°C and 35°C, in Newtons.

7.4.4 A copy of the fitting curve relative to temperature and means for determining any subsequent movement of the propeller are to be placed on board.

7.5 Final fitting of keyed propellers

7.5.1 The fit of the screwshaft cone to both the working and any spare propeller is to be carried out under survey. Generally, a satisfactory fit for keyed type propellers should show a light, overall marking of the cone surface with a tendency towards heavier marking in way of the larger diameter of the cone face. The final fit to cone should be made with the key in place.

■ *Section 8* Water jet units

8.1 Construction and welding

8.1.1 The following components are to be inspected at the manufacturer's works:

- Steering nozzle.
- Reverse bucket.
- Stator impeller.
- Integral bearing.

8.1.2 Welded components are to comply with the requirements of Pt 15, Ch 4 and be subject to stress relief heat treatment upon completion. Where an impeller has welded blades, non-destructive testing is to be carried out to an approved procedure.

8.2 Testing

8.2.1 Testing of the first installation of a new type of water jet unit is required and is to demonstrate the adequacy of the steering and reversing mechanisms during the most arduous manoeuvres.

8.2.2 Upon completion, the impeller assembly is to be suitably balanced in accordance with ISO 940 Grade G6,3 or an equivalent standard.

■ *Section 9* Thrusters

9.1 Azimuth thrusters

9.1.1 The performance specified for the craft is to be demonstrated.

9.1.2 The actual values of steering torque are to be verified during sea trials to confirm that the design maximum dynamic duty torque has not been exceeded.

9.2 Tunnel thrusters

9.2.1 It is to be demonstrated that the thruster unit meets the specified performance.

■ *Section 10* Steering systems

10.1 Construction

10.1.1 The requirements of the Rules relating to the testing of Class I pressure vessels, piping and related fittings including hydraulic testing apply.

10.2 Type testing

10.2.1 Each type of power unit pump is to be subjected to a type test. The type test is to be for a duration of not less than 100 hours, the test arrangements are to be such that the pump may run in idling conditions, and at maximum delivery capacity at maximum working pressure. During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another should occur at least as quickly as on board. During the whole test no abnormal heating, excessive vibration or other irregularities are permitted. After the test, the pump is to be opened out and inspected. Type tests may be waived for a power unit which has been proven to be reliable in marine service.

10.3 Testing

10.3.1 After installation on board the craft the steering unit is to be subjected to the applicable hydrostatic and running tests.

10.3.2 The steering system is to be demonstrated to show that the requirements of the Rules have been met. The trial is to include the operation of the following:

(a) The steering system, including demonstration of the functional performances.
(b) The steering power units, including transfer between steering power units.
(c) The isolation of one power actuating system, checking the time for regaining steering capability.

(d) The hydraulic fluid recharging system (may be effected at the dockside).
(e) The emergency power supply.
(f) The steering controls, including transfer of control and local control.
(g) The means of communication between the steering compartment and the wheelhouse, also the engine room, if applicable (may be effected at the dockside).
(h) The alarms and indicators (may be effected at the dockside).
(j) Where the steering system is designed to avoid hydraulic locking this feature is to be demonstrated (may be effected at the dockside).

■ *Section 11* Sea trials

11.1 Sea trials requirements

11.1.1 Sea trials are to be of sufficient duration and carried out under normal operating conditions applicable to the intended class notation. Individual Chapters give specific requirements.

11.2 Programme

11.2.1 Sea trials are to include the demonstration of:
(a) The adequacy of the starting arrangements of the main engines, auxiliary systems and emergency generators.
(b) The effectiveness of the steering gear control systems.
(c) Manoeuvring, to include:
- starting;
- normal and emergency stopping;
- reversing;
- governor testing;
- safety devices, and associated indicators and alarms.

(d) The redundancy arrangements for Category B craft.
(e) Tooth contact markings in geared installations using a recognised technique. The marking is to be as detailed in 5.5.
(f) For controllable pitch propellers, the pitch setting under failure conditions.

11.3 Performance testing

11.3.1 It is to be verified that the propeller performs satisfactorily under ahead and astern conditions. Where controllable pitch propellers are fitted, the free route astern trial is to be carried out with the propeller blades set in the full pitch astern condition.

11.3.2 It is to be verified that large movements of resiliently mounted machinery do not occur during start up and stop, or during normal operating conditions.

11.3.3 The installation should be tested to ensure that gas turbines cannot be continuously operated within any speed range where excessive vibration, stalling or surging may be encountered.

11.3.4 Overloading of machinery is not to occur under continuous astern power.

RULES AND REGULATIONS FOR THE CLASSIFICATION OF SPECIAL SERVICE CRAFT

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PART 10

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■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 The requirements of Section 4 do not apply to diesel engines intended for essential services where power does not exceed 110 kW.

1.2 Power ratings

1.2.1 In this Chapter where the dimensions of any particular component are determined from shaft power, P, in kW, and revolutions per minute, R, the values to be used are those defined in Part 9.

1.3 Power conditions for generator sets

1.3.1 Auxiliary engines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output (kW) and of developing for a short period (15 minutes) an overload power of not less than 10 per cent, *see* Pt 16, Ch 2.

1.4 Inclination of craft

1.4.1 Main and essential auxiliary diesel engines are to operate satisfactorily under the conditions as shown in Table 1.4.1 in Pt 9, Ch 1.

1.5 Engine type testing

1.5.1 New engine types or developments of existing types are to be subjected to an agreed programme of type testing to complement the design appraisal and review of documentation. The programme will need to include short term high power operation where applicable.

■ *Section 2* Particulars to be submitted

2.1 Plans and information

2.1.1 At least three copies of the following plans are to be submitted for consideration:

- Crankshaft assembly plan (for each crank-throw).
- Crankshaft details plan (for each crank-throw).
- Thrust shaft or intermediate shaft (if integral with engine).
- Output shaft coupling bolts.
- Main engine securing arrangements where non-metallic chocks are used.
- Type and arrangement of crankcase explosion relief valves.
- Arrangement and welding specifications with details of the procedures for fabricated bedplate, thrust bearing bedplate, crankcases, frames and entablatures. Details of materials, welding consumables, fit-up conditions, fabrication sequence and heat treatments are to be included.
- Details of the securing and collision arrangements (*see also* Part 9).
- Schematic oil fuel system, including controls and safety devices.
- Lubricating oil system.
- Starting air system.
- Cooling water system.
- Control engineering aspects in accordance with Part 16.
- Shielding of high pressure fuel pipes.
- Crankshaft design data as outlined in Section 4.
- Combustion pressure-displacement relationship.
- High pressure parts for fuel oil injection system with specification of pressures, pipe dimensions and materials.
- For new engine types that have not been approved by LR, the proposed type test programme.
- The type test report on completion of type testing for a new engine type. For mass produced engines a separate report is to be submitted for each engine requiring approval, *see* 10.5.

- The specification for a mass produced engine including manufacturing processes and quality control procedures, *see* 10.1.4 and 10.2.3.
- Schematic layouts showing details and arrangements of oil mist detection/monitoring and alarm systems.

2.1.2 The following information and calculations are to be submitted for information:

- Power/speed operational envelope.
- Calculations and information for short term high power operation where applicable.
- Longitudinal and transverse cross-section.
- Cast bedplate, thrust bearing bedplate, crankcase and frames.
- Cylinder head assembly.
- Cylinder liner.
- Piston assembly.
- Tie rod.
- Connecting rod, piston rod, and crosshead assemblies.
- Camshaft drive and camshaft general arrangement.
- Shielding and insulation of exhaust pipes.
- Operation and maintenance manuals.
- Vibration dampers/detuners and moment compensators.
- Details of turbochargers.
- Cross-sectional plans of the assembled turbo-charger with main dimensions.
- Fully dimensioned plans of the rotor.
- Material particulars with details of welding and surface treatments.
- Turbo-charger operating and test data.
- Manufacturer's burst test assessment.
- Material specifications covering the listed components together with details of any surface treatments, non-destructive testing and hydraulic tests.
- Arrangement of interior lighting, where provided.
- Engine Type test programme, where required including proposals for short term high power operation.
- Alternative proposals for hydraulic tests where design features are such that modifications to the test requirements are necessary.
- Thrust bearing assembly (if integral with engine and not integrated in the bedplate).
- Counterweights, where attached to crank-throw, including fastening.
- Main engine holding down arrangement (metal chocks).

2.1.3 Where it is proposed to use alloy castings, micro alloyed or alloy steel forgings or iron castings, details of the chemical composition, heat treatment and mechanical properties are to be submitted.

2.1.4 For engine types built under licence it is intended that the above documentation be submitted by the Licensor. Each Licensee is then to submit the following:

- A list, based on the above, of all documents required with the relevant drawing numbers and revision status from both Licensor and Licensee.
- The associated documents where the Licensee proposes design modifications to components. In such cases a statement is to be made confirming the Licensor’s acceptance of the proposed changes.

In all cases a complete set of endorsed documents will be required by the Surveyor attending the Licensee’s works.

2.1.5 A Failure Mode and Effects Analysis (FMEA) as required by Part 9 is to be submitted. The FMEA is to include the following associated sub-systems:

- Starting and stopping.
- Oil fuel.
- Lubricating oil.
- Cooling water (fresh and sea).
- Air induction.
- Exhaust.
- Engine mounting.
- Control and monitoring.
- Electrical power supplies.
- Hydraulic oil (for valve lift).

2.1.6 Where engines incorporate electronic control systems, a failure mode and effects analysis (FMEA) is to be submitted to demonstrate that failure of an electronic control system will not result in the loss of essential services for the operation of the engine and that operation of the engine will not be lost or degraded beyond an acceptable performance criteria of the engine. This is concerned with the functioning of the control system and not failure of the software itself.

2.1.7 Plans and details for dead craft condition starting arrangements are to be submitted for appraisal, *see* 7.1.

2.1.8 Where considered necessary additional documentation may be required.

■ *Section 3* **Materials**

3.1 Materials test and inspections

3.1.1 Components for engines are to be tested as indicated in Table 1.3.1 and in accordance with the relevant requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.2 Crankshaft materials

3.2.1 The specified minimum tensile strength of castings and forgings for crankshafts is to be selected within the following general limits:

(a) Carbon-manganese steel castings –
400 to 550 N/mm^2.

(b) Carbon-manganese steel forgings (normalized and tempered) –
400 to 600 N/mm^2.

(c) Carbon-manganese steel forgings (quenched and tempered) –
not exceeding 700 N/mm^2.

(d) Alloy steel castings –
not exceeding 700 N/mm^2.

(e) Alloy steel forgings –
not exceeding 1000 N/mm^2.

(f) Spheroidal or nodular graphite iron castings –
370 to 800 N/mm^2.

Table 1.3.1 Material testing requirements

Component	Material tests	Non-destructive tests: Magnetic particle or Liquid penetrant	Non-destructive tests: Ultrasonic
Crankshaft	all	all	all
Crankshaft coupling flange (non-integral) for main propulsion engines	above 400 mm bore	—	—
Crankshaft coupling bolts	above 400 mm bore	—	—
Steel piston crowns	above 400 mm bore	above 400 mm bore	all
Piston rods	above 400 mm bore	above 400 mm bore	above 400 mm bore
Connecting rods, including bearing caps	all	all	above 400 mm bore
Crosshead	above 400 mm bore	—	—
Cylinder liner	above 300 mm bore	—	—
Cylinder cover	above 300 mm bore	above 400 mm bore	all
Steel castings for welded bedplates	all	all	all
Steel forgings for welded bedplates	all	—	—
Plates for welded bedplates, frames and entablatures	all	—	—
Crankcases, welded or cast	all	—	—
Tie rods	all	above 400 mm bore	—
Turbo-charger, shaft and rotor	above 300 mm bore	—	—
Bolts and studs for cylinder covers, crossheads, main bearings, connecting rod bearings	above 300 mm bore	above 400 mm bore	—
Steel gear wheels for camshaft drives	above 400 mm bore	above 400 mm bore	—

NOTES
1. For closed-die forged crankshafts the ultrasonic examination may be confined to the initial production and to subsequent occasional checks.
2. Magnetic particle or liquid penetrant testing of tie rods may be confined to the threaded portions and the adjacent material over a length equal to that of the thread.
3. Cylinder covers and liners manufactured from spheroidal or nodular graphite iron castings may not be suitable for ultrasonic NDE, depending upon the grain size and geometry. An alternative NDE procedure is to be agreed with LR.
4. Bore dimensions refer to engine cylinder bores.
5. All required material tests are to be witnessed by the Surveyor unless alternative arrangements have been specifically agreed by LR.
6. For mass produced engines, *see* Section 10.

■ *Section 4* Crankshaft design

4.1 Application

4.1.1 The formulae given in this Section are applicable to solid or semi-built crankshafts, having a main support bearing adjacent to each crankpin, and are intended to be applied to a single crankthrow analysed by the static determinate method.

4.1.2 Alternative methods, including a fully documented stress analysis, will be considered.

4.1.3 Calculations are to be carried out for the maximum continuous power rating for all designed operating conditions. Calculations are to include short term high power operation where applicable.

4.1.4 Designs of crankshafts not included in this scope will be subject to special consideration.

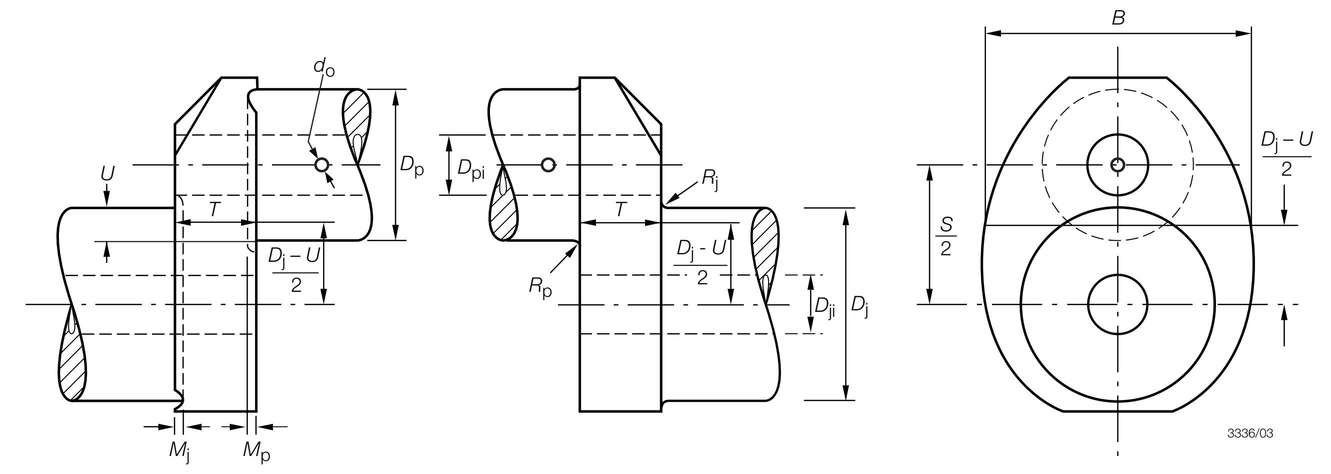
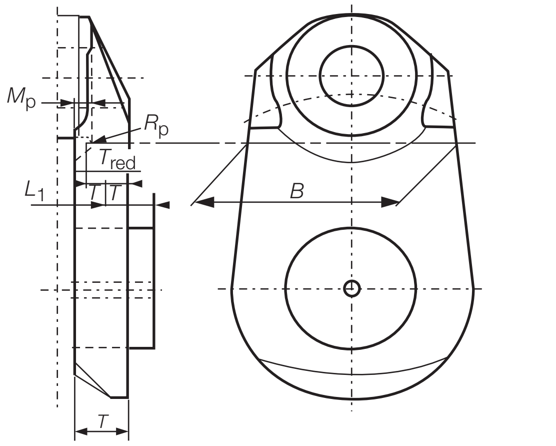


Fig. 1.4.1(a) Crank dimensions necessary for the calculation of stress concentration factors

4.2 Symbols

4.2.1 For the purposes of this Chapter the following symbols apply, *see also* Fig. 1.4.1:

h = radial thickness of web, in mm
k_e = bending stress factor
B = transverse breadth of web, in mm
D_p, D_j = outside diameter of pin or main journal, in mm
D_{pi}, D_{ji} = internal diameter of pin or main journal, in mm
D_s = shrink diameter of main journal in web, in mm
d_o = diameter of radial oil bore in crankpin, in mm
F = alternating force at the web centreline, in N
K_1 = fatigue enhancement factor due to manufacturing process
K_2 = fatigue enhancement factor due to surface treatment
M_b = alternating bending moment at web centreline, in N-mm (NOTE: alternating is taken to be $^1/_2$ range value)
M_{BON} = alternating bending moment calculated at the outlet of crankpin oil bore
M_p, M_j = undercut of fillet radius into web measured from web face, in mm
R_p, R_j = fillet radius at junction of web and pin or journal, in mm
S = stroke, in mm
T = axial thickness of web, in mm
T_a = alternating torsional moment at crankpin or crank journal, in N-mm (NOTE: alternating is taken to be $^1/_2$ range value)
U = pin overlap
α_B = bending stress concentration factor for crankpin
α_T = torsional stress concentration factor for crankpin
β_B = bending stress concentration factor for main journal
β_Q = direct shear stress concentration factor for main journal
β_T = torsional stress concentration factor for main journal
γ_B = bending stress concentration factor for radially drilled oil hole in the crankpin
γ_T = torsional stress concentration factor for radially drilled oil hole in the crankpin
σ_{ax} = alternating axial stress, in N/mm^2
σ_b = alternating bending stress, in N/mm^2
σ_{BON} = alternating bending stress in the outlet of the oil bore, in N/mm^2
σ_p,σ_j = maximum bending stress in pin and main journal taking into account stress raisers, in N/mm^2



Crankshaft without overlap

Fig 1.4.1(b)
Crank dimensions for crankshaft without overlap

σ_u = specified minimum UTS of material, in N/mm^2
σ_y = specified minimum yield stress of material, in N/mm^2
σ_{BO} = maximum bending stress in the outlet of the oil bore, in N/mm^2
σ_Q = alternating direct stress, in N/mm^2
τ_a = alternating torsional stress, in N/mm^2
τ_p, τ_j = maximum torsional stress in pin and main journals taking into account stress raisers, in N/mm^2
τ_{tob}= maximum torsional stress in outlet of crankpin oil bore taking into account stress raisers, in N/mm^2.

4.3 Stress concentration factors

4.3.1 Geometric factors. Crankshaft variables to be used in calculating the geometric stress concentrations together with their limits of applicability are shown in Table 1.4.1.

Table 1.4.1 Crankshaft variables

Variable	Range	
	Lower	Upper
$b = B/D_p$	1,10	2,20
$d_j = D_{ji}/D_p$	0,00	0,80
$d_p = D_{pi}/D_p$	0,00	0,80
$m_j = M_j/D_p$	0,00	r_{jb}
$m_p = M_p/D_p$	0,00	r_p
$r_{jB} = R_j/D_p$	0,03	0,13
$r_{jT} = R_j/D_j$	0,03	0,13
$r_p = R_p/D_p$	0,03	0,13
$t = T/D_p$	0,20	0,80
$t = T_{red}/D_p$ *see* Note 3	0,20	0,80
$d = d_o/D_p$	0,00	0,20
$u = U/D_p$		0,50

NOTES
1. Where variables fall outside the range, alternative methods are to be used and full details submitted for consideration.
2. A lower limit of *u* can be extended down to large negative values provided that:
   (i) If calculated *f*(rec) < 1 then the factor *f*(rec) is not to be considered (*f*(rec) = 1)
   (ii) If *u* < –0,5 then f(ut) and f(ru) are to be evaluated replacing the actual value of *u* by –0,5.
3. For crankshafts without overlap *see also* 4.3.6.

4.3.2 Crankpin stress concentration factors:

Bending

$$\alpha_B = 2{,}70\ f(ut)\ f(t)\ f(b)\ f(r)\ f(dp)\ f(dj)\ f(rec)$$

where

$$f(ut) = 1{,}52 - 4{,}1t + 11{,}2t^2 - 13{,}6t^3 + 6{,}07t^4 - u\,(1{,}86 - 8{,}26t + 18{,}2t^2 - 18{,}5t^3 + 6{,}93t^4) - u^2\,(3{,}84 - 25{,}0t + 70{,}6t^2 - 87{,}0t^3 + 39{,}2t^4)$$

$$f(t) = 2{,}18t^{\,0{,}717}$$

$$f(b) = 0{,}684 - 0{,}0077b + 0{,}147b^2$$

$$f(r) = 0{,}208r_p^{(-0{,}523)}$$

$$f(dp) = 1 + 0{,}315(d_p) - 1{,}52(d_p)^2 + 2{,}41(d_p)^3$$

$$f(dj) = 1 + 0{,}27d_j - 1{,}02(d_j)^2 + 0{,}531(d_j)^3$$

$$f(\text{rec}) = 1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$$

valid only between $u = -\,0{,}5$ and $0{,}5$

Torsion

$$\alpha_T = 0{,}8\ f(ru)\ f(b)\ f(t)$$

where

$$f(ru) = r_p^{\;-(0{,}22\,+\,0{,}1u)}$$

$$f(b) = 7{,}9 - 10{,}65b + 5{,}35b^2 - 0{,}857b^3$$

$$f(t) = t^{\,(-0{,}145)}$$

4.3.3 Crank journal stress concentration factors (not applicable to semi-built crankshafts)

Bending

$$\beta_B = 2{,}71f_B(ut)\ f_B(t)\ f_B(b)\ f_B(r)\ f_B(dj)\ f_B(dp)\ f(rec)$$

where

$$f_B(ut) = 1{,}2 - 0{,}5t + 0{,}32t^2 - u\,(0{,}80 - 1{,}15t + 0{,}55t^2) - u^2\,(2{,}16 - 2{,}33t + 1{,}26t^2)$$

$$f_B(t) = 2{,}24t^{\,0{,}755}$$

$$f_B(b) = 0{,}562 + 0{,}12b + 0{,}118b^2$$

$$f_B(r) = 0{,}191r_{jB}^{(-0{,}557)}$$

$$f_B(dj) = 1 - 0{,}644d_j + 1{,}23(d_j)^2$$

$$f_B(dp) = 1 - 0{,}19d_p + 0{,}0073(d_p)^2$$

$$f(rec) = 1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$$

valid only between $u = -\,0{,}5$ and $0{,}5$

Direct shear

$$\beta_Q = 3{,}01f_Q(u)\ f_Q(t)\ f_Q(b)\ f_Q(r)\ f_Q(dp)\ f(rec)$$

where

$$f_Q(u) = 1{,}08 + 0{,}88u - 1{,}52(u)^2$$

$$f_Q(t) = \frac{t}{0{,}0637 + 0{,}937t}$$

$$f_Q(b) = b - 0{,}5$$

$$f_Q(r) = 0{,}533r_{jB}^{(-0{,}204)}$$

$$f_Q(dp) = 1 - 1{,}19d_p + 1{,}74(d_p)^2$$

$$f(rec) = 1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$$

valid only between $u = -\,0{,}5$ and $0{,}5$

Torsion

$$\beta_T = 0{,}8f(ru)\ f(b)\ f(t)$$

where

$$f(ru) = r_{jT}^{\;-(0{,}22\,+\,0{,}1u)}$$

$$f(b) = 7{,}9 - 10{,}65b + 5{,}35b^2 - 0{,}857b^3$$

$$f(t) = t^{(-0{,}145)}$$

4.3.4 Crankpin oil bore stress concentration factors for radially drilled oil holes:

- Bending

$$\gamma_B = 3 - 5{,}88 \bullet d_o + 34{,}6 \bullet d_o^2$$

- Torsion

$$\gamma_T = 4 - 6 \bullet d_o + 30 \bullet d_o^2$$

4.3.5 Where experimental measurements of the stress concentrations are available these may be used. The full documented analysis of the experimental measurements is to be submitted for consideration.

4.3.6 In the case of semi-built crankshafts when $M_p > R_p$ the web thickness is to be taken as:

$T_{red} = T - (M_p - R_p)$ and the web width *B* is to be taken in way of the crankpin fillet radius centre *see* Fig. 1.4.1(b).

4.4 Nominal stresses

4.4.1 The nominal alternating bending stress, σ_b, is to be calculated from the maximum and minimum bending moment at the web centreline taking into account all forces being applied to the crank throw in one working cycle with the crank throw simply supported at the mid length of the main journals.

4.4.2 Nominal bending stresses are referred to the web bending modulus.

4.4.3 Nominal alternating bending stress:

$$\sigma_b = \pm \frac{M_b}{Z_{web}} k_e \text{ N/mm}^2$$

where

$$Z_{web} = \frac{BT^2}{6} \text{ mm}^3$$

k_e = 0,8 for crosshead engines
= 1,0 for trunk piston engines.

4.4.4 Nominal alternating bending stress in the outlet of the crankpin oil bore:

$$\sigma_{BON} = \pm \frac{M_{BON}}{Z_{crankpin}}$$

where
M_{BON} is taken as the ½ range value
$M_{BON} = \pm ½ (M_{BOmax} - M_{BOmin})$
and
$M_{BO} = (M_{BTO} \cos\psi + M_{BRO} \sin\psi)$, *see* Fig. 1.4.2
The two relevant bending moments are taken in the crankpin cross-section through the oil bore.
M_{BRO} = bending moment of the radial component of the connecting-rod force
M_{BTO} = bending moment of the tangential component of the connecting-rod force

$$Z_{crankpin} = \frac{\pi}{32} \frac{D^4 - d^4}{D}$$ $Z_{crankpin}$ related to the cross-section of axially bored crankpin.

4.4.5 The nominal direct shear stress in the web for the purpose of assessing the main journal is to be added algebraically to the bending stress, using the alternating forces which have been used in deriving M_b in 4.4.3.

4.4.6 Nominal stress is referred to the web cross-section area or the pin cross-section area as applicable.

4.4.7 Nominal alternating direct shear stress:

$$\sigma_Q = \pm \frac{F}{A_{web}} k_e \text{ N/mm}^2$$

where
$A_{web} = BT$ mm²

4.4.8 The nominal alternating torsional stress, τ_a, is to be taken into consideration. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted.

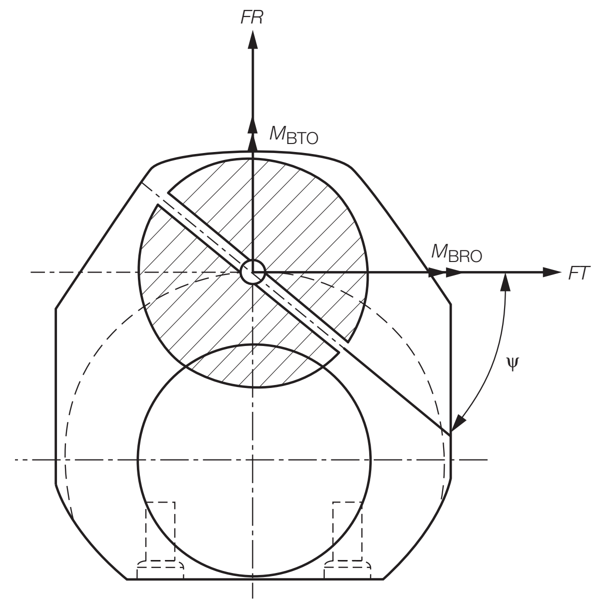


Fig. 1.4.2 Crankpin section through the oil bore

4.4.9 The results of torsional vibration calculations for the full dynamic system, carried out in accordance with Part 13 are to be submitted.

4.4.10 Nominal alternating torsional stress:

$$\tau_a = \pm \frac{T_a}{Z_T} \text{ N/mm}^2$$

where
Z_T = torsional modulus of crankpin and main journal

$$= \frac{\pi}{16} \left[\frac{(D^4 - d^4)}{D}\right] \text{ mm}^3$$

D = outside diameter of crankpin or main journal, in mm
d = inside diameter of crankpin or main journal, in mm
τ_a is to be ascertained from assessment of the torsional vibration calculations where the maximum and minimum torques are determined for every mass point of the complete dynamic system and for the entire speed range by means of a harmonic synthesis of the forced vibrations from the 1st order up to and including the 15th order for 2-stroke cycle engines and from the 0,5th order up to and including the 12th order for 4-stroke cycle engines. Whilst doing so, allowance must be made for the damping that exists in the system and for unfavourable conditions (misfiring [*] in one of the cylinders). The speed step calculation shall be selected in such a way that any resonance found in the operational speed range of the engine shall be detected.

If T_a is not known, a value can be calculated by the following formula as an approximation in the first instance:

$$T_a = \left((18,6 - 0,0132 D_e) \times \left(\frac{\sigma_u + 160}{560}\right)\right) \times Z_e \text{ N/mm}$$

where

$$D_e = D_j \sqrt[3]{1 + \left(\frac{D_{ji}}{D_j}\right)^4}$$

or

$$= D_p \sqrt[3]{1 - \left(\frac{D_{pi}}{D_p}\right)^4}$$

whichever is the smaller

Z_e = corresponding torsional modulus

$$= \pi \frac{(D_e{}^4 - d^4)}{16 D_e} \text{ mm}^3$$

4.4.11 For the purpose of the crankshaft assessment, the nominal alternating torsional stress considered in calculations is to be the highest calculated value, according to the method described in 4.4.10, occurring at the most torsionally loaded mass point of the crankshaft system.

4.4.12 The approval of the crankshaft will be based on the installation having the largest nominal alternating torsional stress (but not exceeding the maximum figure specified by the engine manufacturer). For each installation it is to be ensured by calculation that the maximum approved nominal alternating tersional stress is not exceeded.

4.4.13 Reference should be made to Pt 13, Ch 1 on the calculations of torsional vibration characteristics.

4.4.14 In addition to the bending stress, σ_b, the axial vibratory stress, σ_{ax}, is to be taken into consideration, for crosshead type engines. For trunk piston engines, $\sigma_{ax} = 0$. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted. The corresponding crankshaft free-end deflection is also to be stated.

4.5 Maximum stress levels

4.5.1 Crankpin fillet:

- Maximum alternating bending stress:

$$\sigma_p = \alpha_B (\sigma_b + \sigma_{ax}) \text{ N/mm}^2$$

where

α_B = bending stress concentration, *see* 4.3.2.

- Maximum alternating torsional stress:

$$\tau_p = \alpha_T \tau_{ax} \text{ N/mm}^2$$

where

α_T = torsional stress concentration, *see* 4.3.2

τ_a = nominal alternating torsional stress in crankpin N/mm^2.

4.5.2 Outlet of crankpin oil bore

- Maximum alternating bending stress:

$$\sigma_{BO} = \gamma_B (\sigma_{BON} + \sigma_{ax}) \text{ N/mm}^2$$

where

γ_B = bending stress concentration factor, *see* 4.3.4

- Maximum alternating torsional stress:

$$\tau_{tob} = \gamma_T \tau_a \text{ N/mm}^2$$

where

γ_T = torsional stress concentration factor, *see* 4.3.4

τ_a = nominal alternating torsional stress in crankpin N/mm^2.

4.5.3 Crank journal fillet (not applicable to semi-built crankshafts):

Maximum alternating bending stress:

$$\sigma_j = \beta_B (\sigma_b + \sigma_{ax}) + \beta_Q \sigma_Q \text{ N/mm}^2$$

where

β_B = bending stress concentration, *see* 4.3.3

β_Q = direct stress concentration, *see* 4.3.3.

Maximum alternating torsional stress:

$$\tau_j = \beta_T \tau_a \text{ N/mm}^2$$

where

β_T = torsional stress concentration, *see* 4.3.3

τ_a = nominal alternating torsional stress in main journal N/mm^2.

4.6 Equivalent alternating stress

4.6.1 Equivalent alternating stress of the crankpin, σ_{ep}, or crank journal σ_{ej}, is defined as:

$$\sigma_{ep}, \sigma_{ej} = \sqrt{(\sigma + 10)^2 + 3\tau^2} \text{ N/mm}^2$$

where

σ = σ_p or σ_j N/mm^2

τ = τ_p or τ_j N/mm^2

4.6.2 Equivalent alternating stress for the outlet of the crankpin oil bore σ_{eob}, is defined as:

$$\sigma_{eob} = \pm \frac{1}{3} \sigma_{bo} \left[1 + 2 \sqrt{1 + \frac{9}{4} \left(\frac{\tau_{to}}{\sigma_{bo}}\right)^2} \right] \text{N/mm}^2$$

4.7 Fatigue strength

4.7.1 The fatigue strength of a crankshaft is based upon the crankpin and crank journal as follows:

$$\sigma_{fp} = K_1 K_2 (0{,}42\sigma_u + 39{,}3) \left(0{,}264 + 1{,}073 D_p^{-0{,}2} + \frac{785 - \sigma_u}{4900} + \frac{196}{\sigma_u} \sqrt{\frac{1}{R_p}}\right) \text{ N/mm}^2$$

To calculate the fatigue strength in the oil bore area, replace R_p with ½d_o and σ_{fp} with σ_{fob}.

$$\sigma_{fj} = K_1 K_2 (0{,}42\sigma_u + 39{,}3) \left(0{,}264 + 1{,}073 D_j^{-0{,}2} + \frac{785 - \sigma_u}{4900} + \frac{196}{\sigma_u} \sqrt{\frac{1}{R_j}}\right) \text{ N/mm}^2$$

where

σ_u = UTS of crankpin or crank journal as appropriate, in N/mm^2
K_1 = fatigue endurance factor appropriate to the manufacturing process
= 1,05 for continuous grain-flow (CGF) or die-forged
= 1,0 for freedom forged (without CGF)
= 0,93 for cast steel manufactured using a LR approved cold rolling process
K_2 = fatigue enhancement factor for surface treatment. These treatments are to be applied to the fillet radii.

4.7.2 A value for K_2 will be assigned upon application by the engine designers. Full details of the process, together with the results of full scale fatigue tests will be required to be submitted for consideration. Alternatively, the following values may be taken (surface hardened zone to include fillet radii):
K_2 = 1,15 for induction hardened
= 1,25 for nitrided
Where a value of K_1 or K_2 greater than unity is to be applied then details of the manufacturing process are to be submitted.

4.8 Acceptability criteria

4.8.1 The acceptability factor, Q, is to be greater than 1,15:

$$Q = \frac{\sigma_f}{\sigma_e}$$ for crankpin, journal and the outlet of crankpin oil bore

where
σ_f = σ_{fp}, σ_{fj} or $\sigma_{f\,ob}$
σ_e = σ_{ep}, σ_{ej} or σ_{eob}.

4.9 Crankshaft oil hole

4.9.1 The junction of the oil hole with the crankpin or main journal surface is to be formed with an adequate radius and smooth surface finish down to a minimum depth equal to 1,5 times the oil bore diameter.

4.9.2 Fatigue strength calculations or, alternatively, fatigue test results may be required to demonstrate acceptability.

4.9.3 When journal diameter is equal or larger than the crankpin diameter, the outlets of main journal oil bores are to be formed in a similar way to the crankpin oil bores, otherwise separate fatigue strength calculations or, alternatively, fatigue test results may be required.

4.10 Shrink fit of semi-built crankshafts

4.10.1 The maximum permissible internal diameter in the journal pin is to be calculated in accordance with the following formula:

$$D_{ji} = D_s \sqrt{1 - \frac{4000FoS\,M_{max}}{\mu\,\pi\,D_s^2\,L_s\,\sigma_{yj}}}$$

where the symbols are as defined in 4.10.7.

4.10.2 When 4.10.1 cannot be complied with, then 4.10.7 is not applicable. In such cases δ_{min} and δ_{max} are to be established from FEM calculations.

4.10.3 The following formulae are applicable to crankshafts assembled by shrinking main journals into the crankwebs.

4.10.4 In general, the radius of transition, R_j, between the main journal diameter, D_j, and the shrink diameter, D_s, is to be not less than 0,015D_j or 0,5(D_s – D_j).

4.10.5 The distance, y, between the underside of the pin and the shrink diameter should be greater than 0,05D_s.

4.10.6 Deviations from these parameters will be specially considered.

4.10.7 The proposed diametral interference is to be within the following limits (*see also* Fig. 1.4.3):
The minimum required diametral interference is to be taken as the greater of:

$$\delta_{min} = \frac{12,156 \times 10^6\,(FoS)}{T\,Ds\,\mu\,E}\;\frac{P}{R}\left(1 + C\right)\frac{k^2 - l^2}{(k^2 - 1)(1 - l^2)} \text{ mm}$$

or

$$\delta_{min} = \frac{\sigma_y\,D_s}{E} \text{ mm}$$

where
h = minimum radial thickness of the web around the diameter D_s, mm
$k = \frac{D_o}{D_s}$
$l = \frac{D_{ji}}{D_s}$
C = ratio of torsional vibratory torque to the mean transmitted torque at the P/R rating being considered
D_o = $D_s + 2h$, mm
D_s = shrink diameter, mm
E = Young's modulus of elasticity of crankshaft material, N/mm^2
FoS = Factor of Safety against rotational slippage to be taken as 2,0. A value less than 2,0 may be used where documented by experiments to demonstrate acceptability
P = output power, in kW
R = speed at associated power, in rpm
T = crankweb thickness, in mm
μ = coefficient of static friction to be taken as 0,2 for degreased surfaces. A value greater than 0,2 may be used where documented by experiments to demonstrate acceptability
σ_{yj} = minimum yield strength of material for journal pin
M_{max} = absolute maximum value of the torque taking Ch 8,2 into consideration
L_s = length of shrink fit, in mm

Maximum diametral interference, δ_{max}, is not to be greater than:

$$\delta_{max} = \frac{\sigma_y\,D_s}{E} + \frac{0,8D_s}{1000} \text{ mm}$$

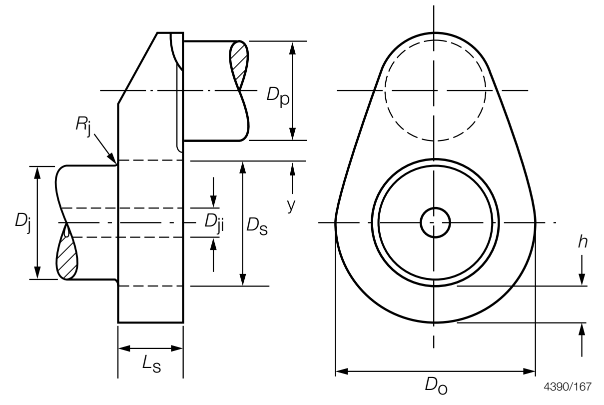


Fig. 1.4.3 Crankthrow of semi-built crankshaft

4.10.8 Reference marks are to be provided on the outer junction of the crankwebs with the journals.

Section 5
Construction and welded structures

5.1 Crankcases

5.1.1 Crankcases and their doors are to be of robust construction to withstand anticipated crankcase pressures that may arise during a crankcase explosion, taking into account the installation of explosion relief valves reuired by Section 6, and the doors are to be securely fastened so that they will not be readily displaced by a crankcase explosion.

5.2 Welded joints

5.2.1 Bedplates and major components of engine structures are to be made with a minimum number of welded joints.

5.2.2 Double welded butt joints are to be adopted wherever possible in view of their superior fatigue strength.

5.2.3 Girder and frame assemblies should, so far as possible, be made from one plate or slab, shaped as necessary, rather than by welding together a number of small pieces.

5.2.4 Steel castings are to be used for parts which would otherwise require complicated weldments.

5.2.5 Care is to be taken to avoid stress concentrations such as sharp corners and abrupt changes in section.

5.2.6 Joints in parts of the engine structure which are stressed by the main gas or inertia loads are to be designed as continuous full strength welds and for complete fusion of the joint. They are to be so arranged that, in general, welds do not intersect, and that welding can be effected without difficulty and adequate inspection can be carried out. Abrupt changes in plate section are to be avoided and where plates of substantially unequal thickness are to be butt welded, the thickness of the heavier plate is to be gradually tapered to that of the thinner plate. Tee joints are to be made with full bevel or equivalent weld preparation to ensure full penetration.

5.2.7 In single plate transverse girders the castings for main bearing housings are to be formed with web extensions which can be butt welded to the flange and vertical web plates of the girder. Stiffeners in the transverse girder are to be attached to the flanges by full penetration welds.

5.3 Materials and construction

5.3.1 Plates, sections, forgings and castings are to be of welding quality in accordance with the requirements of the Rules for Materials, and with a carbon content generally not exceeding 0,23 per cent. Steels with higher carbon contents may be approved subject to satisfactory results from welding procedure tests.

Section 6
Safety arrangements on engines

6.1 Cylinder relief valves

6.1.1 Scavenge spaces in open connection with cylinders are to be provided with explosion relief valves.

6.2 Crankcase relief valves

6.2.1 Crankcases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices to relieve the crankcases of pressure in the event of an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0,2 bar.

6.2.2 The valve lids are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

6.2.3 Each valve is to be fitted with a flame arrester that permits flow for crankcase pressure relief and prevents the passage of flame following a crankcase explosion. The valves are to be type tested in a configuration that represents the installation arrangements that will be used on an engine and in accordance with Section 15. The valves are to be positioned on engines to minimise the possibility of danger and damage arising from emission of the crankcase atmosphere. Where shielding from the emissions is fitted to a valve, the valve is to be type tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valve.

6.2.4 In engines having cylinders not exceeding 200 mm bore or having a crankcase gross volume not exceeding 0,6 m^3, relief valves may be omitted.

6.2.5 In engines having cylinders exceeding 200 mm but not exceeding 250 mm bore, at least two relief valves are to be fitted; each valve is to be located at or near the ends of the crankcase. Where the engine has more than eight crank throws an additional valve is to be fitted near the centre of the engine.

6.2.6 In engines having cylinders exceeding 250 mm but not exceeding 300 mm bore, at least one relief valve is to be fitted in way of each alternate crank throw with a minimum of two valves. For engines having 3, 5, 7, 9, etc., crank throws, the number of relief valves is not to be less than 2, 3, 4, 5, etc., respectively.

6.2.7 In engines having cylinders exceeding 300 mm bore at least one valve is to be fitted in way of each main crank throw.

6.2.8 Additional relief valves are to be fitted for separate spaces on the crankcase, such as gear or chaincases for camshaft or similar drives, when the gross volume of such spaces exceeds 0,6 m^3.

6.2.9 The combined free area of the crankcase relief valves fitted on an engine is to be not less than 115 cm^2/m^3 based on the volume of the crankcase.

6.2.10 The free area of each relief valve is to be not less than 45 cm^2.

6.2.11 The free area of the relief valve is the minimum flow area at any section through the valve when the valve is fully open.

6.2.12 In determining the volume of the crankcase for the purpose of calculating the combined free area of the crankcase relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crankcase. No deduction shall be made for the volumes of the rotating and reciprocating components.

6.2.13 The valves are to be provided with a copy of the manufacturer's installation and maintenance manual for the size and type of valve being supplied for installation on a particular engine. The manual is to contain the following information:

- Description of valve with details of function and design limits.
- Copy of type test certification.
- Installation instructions.
- Maintenance and in-service instructions to include testing and renewal of any sealing arrangements.
- Actions required after a crankcase explosion.

6.2.14 A copy of the installation and maintenance manual required by 6.2.13 is to be provided on board the ship.

6.2.15 Plans showing details and arrangements of the relief valves are to be submitted for approval, *see* 2.1.

6.2.16 The valves are to be provided with suitable markings that include the following information:

- Name and address of manufacturer.
- Designation and size.
- Month/Year of manufacture.
- Approved installation orientation.

6.3 Vent pipes

6.3.1 Through ventilation, and any arrangement which could produce a flow of external air within the crankcase, is in principle not permitted except for trunk piston type dual fuel engines where crankcase ventilation is to be provided. Where crankcase vent or breather pipes are fitted, they are to be made as small as practicable and/or as long as possible to minimize the inrush of air after an explosion. Vent or breather pipes from crankcases of main engines are to be led to a safe position on deck or other approved position.

6.3.2 If provision is made for the extraction of gases from within the crankcase, e.g. for oil mist detection purposes, the vacuum within the crankcase is not to exceed 25 mm of water.

6.3.3 Lubricating oil drain pipes from engine sump to drain tank are to be submerged at their outlet ends. Where two or more engines are installed, vent pipes, if fitted, and lubrication oil drain pipes are to be independent to avoid intercommunication between crankcases.

6.4 Warning notice

6.4.1 A warning notice is to be fitted in a prominent position, preferably on a crankcase door on each side of the engine, or alternatively at the engine room control station. This warning notice is to specify that whenever overheating is suspected in the crankcase, the crankcase doors or sight holes are not to be opened until a reasonable time has elapsed after stopping the engine, sufficient to permit adequate cooling within the crankcase.

6.5 Crankcase access and lighting

6.5.1 Where access to crankcase spaces is necessary for inspection purposes, suitably positioned rungs or equivalent arrangements are to be provided as considered appropriate.

6.5.2 Interior lighting, where fitted, is to be flameproof.

6.6 Oil mist detection/monitoring

6.6.1 Where crankcase oil mist detection/monitoring arrangements are fitted, they are to be of a type approved by LR, tested in accordance with Section 16 and comply with 6.6.2 to 6.6.15.

6.6.2 The oil mist detection/monitoring system and arrangements are to be installed in accordance with the engine designer's and oil mist detection equipment manufacturer's instructions/recommendations. The following particulars are to be included in the instructions:

(a) Schematic layout of engine oil mist detection/monitoring and alarm system showing locations of engine crankcase sample points and piping arrangements together with pipe dimensions to detector/monitor.
(b) Evidence of study to justify the selected locations of sample points and sample extraction rate (if applicable) in consideration of the crankcase arrangements and geometry, and the predicted crankcase atmosphere where oil mist can accumulate.
(c) The manufacturer's maintenance and test manual.
(d) Information relating to type or in-service testing of the engine with engine protection system test arrangements having approved types of oil mist monitoring equipment.

6.6.3 A copy of the oil mist detection/monitoring equipment maintenance and test manual required by 6.6.2 is to be provided on board ship.

6.6.4 Oil mist monitoring and alarm information is to be capable of being read from a safe location away from the engine.

6.6.5 In the case of multi engine installations, each engine is to be provided with oil mist detection/monitoring and a dedicated alarm.

6.6.6 Oil mist detection/monitoring and alarm systems are to be capable of being tested on the test bed and on board when the engine is at a standstill and when the engine is running at normal operating conditions in accordance with test procedures that are acceptable to LR.

6.6.7 Alarms and shutdowns for the oil mist detection/monitoring system are to be in accordance with Pt 16, Ch 1 as applicable.

6.6.8 The oil mist detection/monitoring arrangements are to provide an alarm indication in the event of a foreseeable functional failure in the equipment and installation arrangements.

6.6.9 The oil mist detection/monitoring system is to provide an indication that any lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication.

6.6.10 Where oil mist detection/monitoring equipment includes the use of programmable electronic systems, the arrangements are to be in accordance with Pt 16, Ch 1, as applicable.

6.6.11 Schematic layouts showing details and arrangements of oil mist detection/monitoring and alarm systems are to be submitted. *See* 2.1.

6.6.12 The equipment together with detectors/monitors is to be tested when installed on the test bed and on board ship to demonstrate that the detection/monitoring and alarm system functions correctly. The testing arrangements are to be to the satisfaction of the Surveyor.

6.6.13 Where sequential oil mist detection/monitoring arrangements are provided, the sampling frequency and time is to be as short as reasonably practicable.

6.6.14 Where alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, detailed information is to be submitted for consideration. The information is to include:

(a) Engine particulars - type, power, speed, stroke, bore and crankcase volume.
(b) Details of arrangements designed to prevent the build up of potentially explosive conditions within the crankcase, e.g., bearing temperature monitoring, oil splash temperature monitoring, crankcase pressure monitoring, and recirculation arrangements.
(c) Evidence to demonstrate that the arrangements are effective in preventing the build up of potentially explosive conditions together with details of in-service experience.
(d) Operating instructions and the maintenance and test instructions.

6.6.15 Where it is proposed to use the introduction of inert gas into the crankcase to minimise a potential crankcase explosion, details of the arrangements are to be submitted for consideration.

■ *Section 7* **Starting arrangements**

7.1 Dead craft condition starting arrangements

7.1.1 Means are to be provided to ensure that machinery can be brought into operation from the dead craft condition without external aid.

7.1.2 Dead craft condition for the purpose of 7.1.1 is to be understood to mean a condition under which the main propulsion plant and auxiliaries are not in operation. In restoring propulsion, no stored energy for starting and operating the propulsion plant is assumed to be available. Additionally, neither the main source of electrical power nor other essential auxiliaries is assumed to be available for starting and operating the propulsion plant.

7.1.3 Where the emergency source of power is an emergency generator which fully complies with the requirements of Pt 16, Ch 2 of the Rules, this generator may be used for restoring operation of the main propulsion plant, boilers and auxiliaries where any power supplies necessary for engine operation are also protected to a similar level as the starting arrangements.

7.1.4 Where there is no emergency generator installed or an emergency generator does not comply with Pt 16, Ch 2, the arrangements for bringing main and auxiliary machinery into operation are to be such that the initial charge of starting air or initial electrical power and any power supplies for engine operation can be developed on board the craft without external aid. If, for this purpose, an emergency air compressor or an electric generator is required, these units are to be powered by a hand-starting oil engine or a hand-operated compressor. The arrangements for bringing main and auxiliary machinery into operation are to have capacity such that the starting energy and any power supplies for engine operation are available within 30 minutes of a dead craft condition.

7.2 Starting arrangements – Air compressors

7.2.1 Two or more air compressors are to be fitted having a total capacity, together with a topping-up compressor where fitted, capable of charging the air receivers within one hour from atmospheric pressure, to the pressure sufficient for the number of starts required by 7.3. At least one of the air compressors is to be independent of the main propulsion unit and the capacity of the main air compressors is to be approximately equally divided between them. The capacity of an emergency compressor which may be installed to satisfy the requirements of 7.1 is to be ignored.

7.2.2 The compressors are to be so designed that the temperature of the air discharged to the starting air receivers will not substantially exceed 93°C in service. A small fusible plug or an alarm device operating at 121°C is to be provided on each compressor to give warning of excessive air temperature. The emergency air compressor is excepted from these requirements.

7.2.3 Each compressor is to be fitted with a safety valve so proportioned and adjusted that the accumulation with the outlet valve closed will not exceed 10 per cent of the maximum working pressure. The casings of the cooling water spaces are to be fitted with a safety valve or bursting disc so that ample relief will be provided in the event of the bursting of an air cooler tube.

7.2.4 Each compressor is to be fitted with an alarm for failure of the lubricating oil supply which will initiate an automatic shutdown.

7.3 Air receivers

7.3.1 Where the main engine is arranged for air starting the total air receiver capacity is to be sufficient to provide without replenishment, not less than 12 consecutive starts of the main engine, alternating between ahead and astern if of the reversible type and not less than six consecutive starts if of the non-reversible type. At least two air receivers of approximately equal capacity are to be provided. For scantlings and fittings of air receivers, *see* Pt 15, Ch 4.

7.3.2 For multi-engine installations, where more than one engine is driving each propulsion shaft line, the following requirements apply:

(a) Twin engine installations driving fixed pitch propeller, where one of the engines can be reversed, six consecutive starts per engine are required.
(b) For all other types of multi-engine installations three consecutive starts per engine are required.

7.3.3 Each air receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

7.3.4 Each receiver which can be isolated from a relief valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C, *see also* Pt 15, Ch 4,9.2.

7.3.5 Receivers used for the storage of air for the control of remotely operated valves are to be fitted with relief valves and not fusible plugs.

7.4 Starting air pipe systems and safety fittings

7.4.1 Air start piping systems are in general to comply with the requirements of Part 15, due regard being paid to the particular type of installation.

7.4.2 In designing the compressed air installation, care is to be taken that the compressor air inlets will be located in an atmosphere reasonably free from oil vapour or, alternatively, an air duct from outside the machinery space is to be led to the compressors.

7.4.3 The air discharge pipe from the compressors is to be led direct to the starting air receivers. Provision is to be made for intercepting and draining oil and water in the air discharge for which purpose a separator or filter is to be fitted in the discharge pipe between compressors and receivers.

7.4.4 The starting air pipe system from receivers to main and auxiliary engines is to be entirely separate from the compressor discharge pipe system. Stop valves on the receivers are to permit slow opening to avoid sudden pressure rises in the piping system. Valve chests and fittings in the piping system are to be of ductile material.

7.4.5 Drain valves for removing accumulations of oil and water are to be fitted on compressors, separators, filters and receivers. In the case of any low-level pipelines, drain valves are to be fitted to suitably located drain pots or separators.

7.4.6 The starting air piping system is to be protected against the effects of explosions by providing an isolating non-return valve or equivalent at the starting air supply to each engine.

7.4.7 In direct reversing engines bursting discs or flame arresters are to be fitted at the starting valves on each cylinder; in non-reversing and auxiliary engines at least one such device is to be fitted at the supply inlet to the starting air manifold on each engine. The fitting of bursting discs or flame arresters may be waived in engines where the cylinder bore does not exceed 230 mm.

7.4.8 Alternative safety arrangements may be submitted for consideration.

7.5 Electrical starting arrangements

7.5.1 Where main engines are fitted with electric starters, two batteries are to be fitted. Each battery is to be capable of starting the engines when cold and the combined capacity is to be sufficient without recharging to provide the number of starts of the main engines as required by 7.3.

7.5.2 Electric starting arrangements for auxiliary engines are to have two separate batteries or be supplied by separate circuits from the main engine batteries when such are provided. Where one of the auxiliary engines only is fitted with an electric starter one battery will be acceptable.

7.5.3 The combined capacity of the batteries for starting the auxiliary engines is to be sufficient for at least three starts for each engine.

7.5.4 Engine starting batteries are to be used only for the purposes of starting the engines and for the engines' own monitoring arrangements. Means are to be provided to ensure that the stored energy in the batteries is maintained at a level required to start the engines as defined in 7.5.1 and 7.5.3.

7.5.5 Where engines are fitted with electric starting batteries, an alarm is to be provided for low battery level.

7.5.6 The requirements for battery installations are given in Pt 16, Ch 2.

7.6 Starting of the emergency source of power

7.6.1 Emergency generators are to be capable of being readily started in their cold conditions down to a temperature of 10°C. If this is impracticable, or if lower temperatures are likely to be encountered, consideration is to be given to the provision and maintenance of heating arrangements, so that ready starting will be assured.

7.6.2 Each emergency generator that is arranged to be automatically started is to be equipped with an approved starting system having two independent sources of stored energy, each of which is sufficient for at least three consecutive starts. When hand (manual) starting is demonstrated to be effective, only one source of stored energy need be provided. However, this source of stored energy is to be protected against depletion below the level required for starting.

7.6.3 Provision is to be made to maintain continuously the stored energy at all times, and for this purpose:

(a) Electrical and hydraulic starting systems are to be maintained from the emergency switchboard.

(b) Compressed air starting systems may be maintained by the main or auxiliary compressed air receivers, through a suitable non-return valve, or by an emergency air compressor energized by the emergency switchboard.

(c) All these starting, charging and energy storing devices are to be located in the emergency generator room. These devices are not to be used for any purpose other than the operation of the emergency generator.

7.6.4 When automatic starting is not required by the Rules and where it can be demonstrated as being effective, hand (manual) starting is permissible, such as manual cranking, inertial starters, manual hydraulic accumulators, powder charge cartridges.

7.6.5 When hand (manual) starting is not practicable, the provisions of 7.6.2 and 7.6.3 are to be complied with except that starting may be manually initiated.

7.6.6 Engine starting batteries are to be used only for the purposes of starting the engines and for the engines' own monitoring arrangements.

■ *Section 8* Piping systems

8.1 General

8.1.1 Diesel engine piping systems are, in general, to comply with the requirements of Pt 15, Ch 1 and Ch 3, due regard being paid to the particular type of installation.

8.1.2 Short lengths of synthetic rubber hoses that comply with the requirements of Pt 15, Ch 1,13 may be used in diesel engine piping systems to accommodate relative movement between machinery and fixed piping systems.

8.2 Oil fuel systems

8.2.1 Oil fuel arrangements are to comply with the requirements of Pt 15, Ch 3,3 and 3,4, as applicable.

8.2.2 All external high pressure fuel delivery lines between the high pressure fuel pumps and fuel injectors are to be protected with a jacketed piping system capable of containing fuel from a high pressure line failure. If flexible hoses are used for shielding purposes, these arrangements are to be approved.

8.2.3 The protection is to prevent oil fuel or oil fuel mist from reaching a source of ignition on the engine or its surroundings. Suitable drainage arrangements are to be made for draining any oil fuel leakage and for preventing contamination of the lubricating oil by oil fuel.

8.3 Oil fuel filters and fittings

8.3.1 Two or more filters are to be fitted in the oil fuel supply lines to the main and auxiliary engines, and the arrangements are to be such that any filter can be cleaned without interrupting the supply of filtered oil fuel to the engines.

8.3.2 Drip trays are to be fitted under oil fuel filters and other fittings which are required to be opened up frequently for cleaning or adjustment or where there is the possibility of leakage. Alternative arrangements may be acceptable and full details should be submitted for consideration.

8.4 Lubricating oil systems

8.4.1 Lubricating oil arrangements are to comply with the requirements of Part 15 as applicable.

8.5 Engine cooling water systems

8.5.1 Cooling water arrangements are to comply with the requirements of Part 15, as applicable.

8.6 Inlet and exhaust systems

8.6.1 Engine inlets are to be arranged to provide sufficient air to the engines whilst minimising the ingestion of harmful particles.

8.6.2 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back to the engine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard. Erosion/corrosion resistant shut-off flaps or other devices are to be fitted on the hull side shell or pipe end and acceptable arrangements made to prevent water flooding the space or entering the engine exhaust manifold.

8.6.3 Where the exhausts of two or more engines are led to a common silencer or exhaust gas-heated boiler or economizer, an isolating device is to be provided in each exhaust pipe.

8.6.4 The arrangement of the exhaust system is to be such as to prevent exhaust gases being drawn into the manned spaces, air conditioning systems and air intakes. They should not discharge into air cushion intakes.

8.7 High pressure oil systems

8.7.1 Where flammable oils are used in high pressure systems, the oil pipe lines between the high pressure oil pump and actuating oil pistons are to be protected with a jacketed piping system capable of preventing oil spray from a high pressure line failure.

■ *Section 9*
Control and monitoring

9.1 General

9.1.1 The Control and Monitoring systems are to comply with the requirements of Part 16.

9.1.2 While it is recommended that oil mist monitoring, engine bearing temperature monitors or alternative methods for crankcase protection be fitted, they are in any case to be provided:

(a) When arrangements are fitted to override the automatic stop for excessive reduction of the lubricating oil supply pressure.

(b) For engines of 2,250 kW and above or having cylinders of more than 300 mm bore.

Notes:

1. For medium and high speed engines automatic shutdown of the engine is to occur, *see also* 9.7.2.
2. Where alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, details are to be submitted for consideration. The submission is to demonstrate that the arrangements are equivalent to those provided by oil mist monitoring or engine bearing temperature monitors, *see* 6.6.14.

9.1.3 All main and auxiliary engines intended for essential services are to be provided with means of indicating the lubricating oil pressure supply to them. Where such engines are of more than 220 kW, audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. Further, these alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

9.2 Main engine governors

9.2.1 An efficient governor is to be fitted to each main engine so adjusted that the speed does not exceed that for which the engine is to be classed by more than 15 per cent.

9.3 Auxiliary engine governors

9.3.1 Auxiliary engines intended for driving electric generators are to be fitted with governors which, with fixed setting, are to control the speed within 10 per cent momentary variation and 5 per cent permanent variation under the following conditions:

(a) Full load is suddenly taken off.

(b) Full load is suddenly applied following a minimum of 15 minutes no load. If the BMEP is greater than 8 bar the load may be applied as follows:

$$\frac{800}{BMEP}\ \%\ \left(\text{but not less than } \frac{1}{3} \text{ full load}\right), \text{ then full load}$$

being attained in not more than two equal stages as rapidly as possible.

9.3.2 Emergency engines are to comply with 9.3.1 except that the initial load required by 9.3.1(b) is to be not less than the total connected emergency statutory load.

9.3.3 For alternating current installations, the permanent speed variation of the machines intended for parallel operation are to be equal within a tolerance of ± 0,5 per cent. Momentary speed variations with load changes in accordance with 9.5.1 are to return to and remain within one per cent of the final steady state speed in not more than eight seconds.

9.4 Overspeed protective devices

9.4.1 Each main engine developing 220 kW or over which can be declutched or which drives a controllable (reversible) pitch propeller, also each auxiliary engine developing 220 kW and over for driving an electric generator, is to be fitted with an approved overspeed protective device.

9.4.2 The overspeed protective device, including its driving mechanism, is to be independent of the governor required by 9.4 or 9.5 and is to be so adjusted that the speed does not exceed that for which the engine and its driven machinery are to be classed by more than 20 per cent for main engines and 15 per cent for auxiliary engines.

9.5 Engine stopping

9.5.1 At least two independent means of stopping the engines quickly from the control station under any conditions are to be available.

9.6 Unattended machinery

9.6.1 Where machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with the alarms and safety arrangements required by 9.1 to 9.8 as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

9.6.2 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery are required by Tables 1.9.1 and 1.9.2, the sensors and circuits utilised for the second stage alarm and automatic shutdown are to be independent of those required for the first stage alarm.

9.6.3 Means are to be provided to prevent leaks from high pressure oil fuel injection piping for main and auxiliary engines dripping or spraying onto hot surfaces or into machinery air inlets. Such leakage is to be collected and, where practicable, led to a collector tank(s) fitted in a safe position. An alarm is to be provided to indicate that leakage is taking place. These requirements may also be applicable to high pressure hydraulic oil piping depending upon the location.

9.6.4 Where machinery specified in this Section is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

9.7 Diesel engines for propulsion purposes

9.7.1 Alarms and safeguards are indicated in 9.7.2 to 9.7.8 and Table 1.9.1, *see also* 9.1.2 and 9.6.3.

9.7.2 Alarms are to operate, and indication is to be given at the relevant control stations that the speed or power of the main propulsion engine(s) is to be reduced for the following fault conditions:

(a) Oil mist in crankcase or high bearing temperature (if detection is fitted, *see* 9.1.2).
(b) Low piston coolant pressure or flow.
(c) High piston coolant outlet temperature.
(d) Low cylinder coolant pressure or flow.
(e) High cylinder coolant temperature.
(f) High exhaust gas temperature per cylinder or deviation from average temperature (high).
(g) High thrust bearing temperature.
(h) Low cylinder lubricator flow.

NOTES:

1. For medium and high speed engines automatic slowdown is required for items (d), (e), (f) and (h). However, an automatic shutdown is required for (a).
2. Common sensors are acceptable for alarms and slowdown functions.

9.7.3 Reduction of speed or power may be effected by either manual or automatic control.

9.7.4 The following engine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the propulsion engine(s):

(a) Lubricating oil supply.
(b) Piston coolant supply, where applicable.
(c) Cylinder coolant supply, where applicable.
(d) Fuel valve coolant supply, where applicable.

9.7.5 Indication of the starting air pressure is to be provided at each control station from which it is possible to start the main propulsion engine(s).

9.7.6 The number of automatic consecutive attempts which fail to produce a start is to be limited to three attempts. For reversible engines which are started and stopped for manoeuvring purposes, means are to be provided to maintain sufficient starting air in the air receivers. For electric starting, *see* 7.5.

9.7.7 Prolonged running in a restricted speed range is to be prevented automatically or, alternatively, an indication of restricted speed ranges is to be provided at each control station.

Table 1.9.1 Oil engines for propulsion purposes alarms and safeguards (*see continuation*)

Item	Alarm	Note
Lubricating oil sump level	Low	Engines (and gearing if fitted)
Lubricating oil inlet pressure*++	1st stage Low++	Engines (and gearing if fitted)
	2nd stage Low	Automatic shutdown engines (and gearing if fitted), *see* 9.6.2
Lubricating oil inlet temperature*	High	Engines (and gearing if fitted)
Lubricating oil filters differential pressure	High	—
Cylinder lubricator flow	Low unit	One sensor per lubricator
Piston coolant inlet pressure	Low	If a separate system
Piston coolant outlet temperature*	High	Per cylinder (if a separate system)
Piston coolant outlet flow*	Low	Per cylinder (if a separate system)
Cylinder coolant inlet pressure or flow*++	Low	—
Cylinder coolant outlet temperature*++	1st stage High++	Per cylinder (if a separate system) or manifold++
	2nd stage High	Automatic shutdown medium and high speed engines, *see* 9.6.2
Sea-water cooling pressure	Low	—
Thrust bearing temperature*	High	—
Fuel valve coolant pressure	Low	If a separate system
Fuel valve coolant temperature	High	If a separate system
Oil fuel pressure from booster pump	Low	—
Oil fuel temperature or viscosity*	High and Low	Heavy oil only
Charge air cooler outlet temperature	High and Low	4 stroke medium and high speed engines
Scavenge air temperature	High	Per cylinder, (fire detection, 2 stroke engines)
Exhaust gas temperature*	High	Per cylinder (or deviation from average temperature)
Turbo-charger exhaust gas outlet temperature*	High	—
Turbo-charger lubricating oil inlet pressure	Low	If system not integral with turbo-charger

Table 1.9.1 Oil engines for propulsion purposes alarms and safeguards (*conclusion*)

Item	Alarm	Note
Turbo-charger lubricating oil inlet temperature	High	If system not integral with turbo-charger
Starting air pressure*	Low	Before engine manoeuvring valve
Overspeed*	High	*See* 9.4
Automatic start of engine	Failure	*See* 9.7.6
Electrical starting battery charge level	Low	—

NOTES
1. Where 'per cylinder' appears in this Table, suitable alarms may be situated on manifold outlets for medium and high speed engines.
2. For engines and gearing of 1500 kW or less, only the items marked* are required.
3. For service craft with engines of 500 kW or less, only the items marked ++ are required.

Table 1.9.2 Auxiliary engine alarms and safeguards

Item	Alarm	Note
Lubricating oil inlet temperature	High	—
Lubricating oil inlet pressure	1st stage Low	—
	2nd stage Low	Automatic shutdown of engine, *see* 9.6.2
Coolant outlet temperature	1st stage High	For engines over 220 kW
	2nd stage High	For engines over 220 kW Automatic shutdown of engine, *see* 9.6.2
Coolant pressure or flow	Low	—
Overspeed	High	*See* 9.4
Starting air pressure	Low	—
Electrical starting battery charge level	Low	—
Oil fuel inlet temperature or viscosity	High and low	Heavy oil only

9.8 Auxiliary and other engines

9.8.1 Alarms and safeguards are indicated in Table 1.9.2, *see also* 9.1.2 and 9.6.3.

9.8.2 For engines operating on heavy oil fuel, automatic temperature of viscosity controls is to be provided.

9.9 Alarms and safeguards for emergency diesel engines

9.9.1 These requirements apply to emergency diesel engines required to be immediately available in an emergency and capable of being controlled remotely or automatically.

9.9.2 Alarms and safeguards are indicated in Table 1.9.3. *See also* 9.1.2 and 9.6.3.

Table 1.9.3 Alarms and safeguards for emergency diesel engines

Item Emergency diesel engine	Alarm ≥ 220 kW	Alarm <220 kW	Note
Fuel oil leakage from pressure pipes	Leakage	Leakage	*See* 9.6.3
Lubricating oil temperature	High	—	—
Lubricating oil pressure	Low	Low	—
Oil mist concentration in crankcase	High	—	*See* Note
Coolant pressure or flow	Low	—	—
Coolant temperature (can be air)	High	High	—
Overspeed	High	—	Automatic shutdown

NOTE
For engines having a power of more than 2250 kW or a cylinder bore of more than 300 mm.

9.9.3 The safety and alarm systems are to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the system and its associated machinery, but also the complete installation, as well as the craft.

9.9.4 Regardless of the engine output, if shutdowns additional to those specified in Table 1.9.3 are provided except for the overspeed shutdown, they are to be automatically overridden when the engine is in automatic or remote control mode during navigation.

9.9.5 Grouped alarms of at least those items listed in Table 1.9.3 are to be arranged on the bridge.

9.9.6 In addition to the fuel oil control from outside the space, a local means of engine shutdown is to be provided.

9.9.7 Local indications of at least those items listed in Table 1.9.3 are to be provided within the same space as the diesel engines and are to remain operational in the event of failure of the alarm and safety systems.

■ *Section 10*
Requirements for craft which are not required to comply with the HSC Code

10.1 General

10.1.1 The requirements of Sections 1 to 9 apply to craft which are not required to comply with the HSC code, unless specifically exempted by the contents of this Section.

10.1.2 The requirements of 1.4.1 do not apply to yachts or service craft less than 24 m.

10.1.3 The requirements of 1.5.1 do not apply to service craft less than 24 m.

10.2 Details to be submitted

10.2.1 The requirements of 2.1.1 do not apply to yachts or service craft less than 24 m, *see* Pt 9, Ch 1,6.1.

10.2.2 The requirements of 2.1.5 (FMEA as detailed in Part 9) do not apply to yachts or to service craft less than 24 m unless used for passenger carrying duties.

10.3 Materials

10.3.1 Materials for which no provision is made in this Part of the Rules may be accepted provided that they comply with an approved specification and such tests as may be considered necessary.

10.4 Crankshaft design

10.4.1 The requirements of Section 4 do not apply to the following types of craft having main or auxiliary diesel engines with a power output not exceeding 110 kW:
(a) service craft of less than 24 m,
(b) yachts,
(c) ACVs.

Section 11
Mass produced engines

11.1 Definition

11.1.1 Mass produced engines, for main and auxiliary purposes, are defined as those which are produced under the following criteria:

(a) In quantity under strict quality control of material and parts, according to a quality assurance scheme acceptable to LR.
(b) By the use of jigs and automatic machine tools designed to machine parts to specified tolerances for interchangeability, and which are verified on a regular inspection basis.
(c) By assembly with parts taken from stock and requiring little or no fitting.
(d) With bench tests carried out on individual assembled engines according to a specified programme.
(e) With appraisal by final examination of engines selected at random after workshop testing.

11.1.2 Castings, forgings and other parts for use in mass produced engines are also to be produced by methods similar to those given in 11.1.1 (a), (b) and (c), with appropriate inspection.

11.1.3 Pressure testing of components is to comply with Pt 9, Ch 2,2.2.

11.1.4 The specification of a mass produced engine is to define the limits of manufacture of all component parts. The total production output is to be certified by the manufacturer and verified as may be required, by LR in accordance with the agreed manufacturer's quality assurance scheme, *see* 11.1.1(a).

11.2 Procedure for approval of mass produced engines

11.2.1 The procedure outlined in 11.2.2 to 11.2.5 applies to the inspection and certification of mass produced oil engines having a bore not exceeding 300 mm.

11.2.2 For the approval of a mass produced engine type, the manufacturer is to submit, in addition to the plans and particulars required by Pt 10, Ch 2, a list of subcontractors for main parts.

11.2.3 The manufacturer is to supply full information regarding the manufacturing processes and quality control procedures applied in the workshops. The information is to address the following:

(a) Organisation of quality control systems.
(b) Recording of quality control operations.
(c) Qualification and independence of personnel in charge of quality control.

11.2.4 A running type test of at least 100 hours duration is to be carried out on an engine chosen from the production line. The type testing is to comply with 11.5.

11.2.5 LR reserves the right to limit the duration of validity of approval of a mass produced engine. LR is to be informed, without delay, of any change in the design of the engine, in the manufacturing or control processes, in the selection of materials or in the list of subcontractors for main parts.

11.3 Continuous review of production

11.3.1 LR Surveyors are to be provided free access to the manufacturer's workshops and to the quality control files.

11.3.2 The control of production, which is subject to survey, is to include the following:

(a) Inspection and testing records are to be maintained to the satisfaction of the Surveyor.
(b) The system for identification of parts is to be in accordance with recognised practice, and acceptable to LR.
(c) The manufacturer is to provide full information about the quality control of the parts supplied by subcontractors for which certification may be required. LR reserves the right to apply direct and individual inspection procedures for parts supplied by subcontractors when deemed necessary.
(d) At the request of an attending LR surveyor, a workshop test may be required for an individual engine.

11.4 Compliance and inspection certificate

11.4.1 Each engine which is to be installed on a ship classed by LR is to be supplied with a statement certifying that the engine is identical to the one which underwent the tests specified in 11.2.4, and state the test and inspection results. The statement is to be made on a form agreed with LR. Each statement is to include the identification number which appears on the engine. A copy of this statement is to be submitted to LR.

11.5 Type test conditions

11.5.1 The requirements in this Section are applicable to the type testing of mass produced internal combustion engines where the manufacturer has requested approval. Omission or simplification of the type test requirements will be considered by LR for engines of an established type on application by the manufacturer.

11.5.2 The engine to be tested is to be selected from the production line and agreed by LR.

11.5.3 The duration and programme of type tests is to include the following:

(a) 80 h at rated output.
(b) 8 h at 110 per cent overload.
(c) 10 h at varying partial loads (25 per cent, 50 per cent, 75 per cent and 90 per cent of rated output).
(d) 2 h at maximum intermittent loads.
(e) Starting tests.
(f) Reverse running of direct reversing engines.
(g) Testing of speed governor.
(h) Testing of over-speed device.

(j) Testing of lubricating oil system failure alarm device.
(k) Testing of the engine with turbocharger out of action when applicable.
(l) Testing of minimum speed for main propulsion engines and the idling speed for auxiliary engines.

11.5.4 The type tests in 11.5.3 at the required outputs are to be combined together in working cycles for the whole duration within the limits indicated. *See also* 11.5.10 and 11.5.11.

11.5.5 The overload testing required by 11.5.3 is to be carried out with the following conditons:
(a) 110 per cent of rated power at 103 per cent revolutions per minute for engines directly driving propellers.
(b) 110 per cent of rated power at 100 per cent revolutions per minute for engines driving electrical generators or for other auxiliary purposes.

11.5.6 For prototype engines, the duration and programme of tests are to be specially agreed between the manufacturer and LR.

11.5.7 As far as practicable during type testing, the following particulars are to be continuously recorded:
(a) Ambient air temperature.
(b) Ambient air pressure.
(c) Atmospheric humidity.
(d) External cooling water temperature.
(e) Fuel and lubrication oil characteristics.

11.5.8 In addition to the particulars stated in 11.5.7 and as far as practicable, the following are also to be continuosly measured and recorded:
(a) Engine revolutions per minute.
(b) Brake power.
(c) Torque.
(d) Maximum combustion pressure.
(e) Indicator pressure diagrams where practicable.
(f) Exhaust smoke (with an approved smoke meter).
(g) Lubricating oil pressure and temperature.
(h) Exhaust gas temperature in exhaust manifold, and, where facilities are available, from each cylinder.
(j) For turbocharged engines:
- Turbocharger revolutions per minute.
- Air temperature and pressures before and after turbo-blower and charge cooler.
- Exhaust gas temperature and pressures before and after the turbine.
- The cooling water inlet temperature to the charge air cooler.

11.5.9 After the type test, the main parts and especially those subject to wear are to be dismantled for examination by LR Surveyors.

11.5.10 For engines that are required to be approved for different purposes (multi-purpose engines), and that have different performances for each purpose, the programme and duration of test is to be modified to cover the whole range of the engine performance, taking into account the most severe conditions and intended purpose(s).

11.5.11 The rated output for which the engine is to be tested is the output corresponding to that declared by the manufacturer and agreed by LR, i.e. actual maximum power which the engine is capable of delivering continuously between the normal maintenance intervals stated by the manufacturer at the rated speed and under the stated ambient conditions.

■ *Section 12*
Mass produced turbo-chargers

12.1 Application

12.1.1 The following procedure applies to the inspection of exhaust driven turbo chargers which are manufactured on the basis of mass production methods similar to 11.1 as applicable and for which the maker has requested the approval.

12.2 Procedure for approval of mass produced turbo-chargers

12.2.1 The procedure outlined in 12.2.2 to 12.2.5 applies to the inspection and certification of mass produced turbo-chargers when a simplified method of inspection has been requested by the manufacturers.

12.2.2 For the approval of a mass produced turbo-charger, the manufacturer is to submit, in addition to the plans and particulars required by Pt 10, Ch 1, as applicable, a list of main current suppliers and subcontractors for rotating parts and an operation and maintenance manual.

12.2.3 The manufacturer will supply full information regarding the material and quality control system used in the organization as well as the inspection methods, the way of recording and proposed frequency, and the method of material testing of important parts.

12.2.4 A Type test, *see* Pt 9, Ch 2,3.1, is to be carried out on a standard unit taken from the assembly line and is to be witnessed by the Surveyor. The performance data which may have to be verified are to be made available at the time of the type test. For manufacturers who have facilities for testing the turbo-charger unit on an engine for which the turbo-charger is intended, substitution of the hot running test by a test run of one hour's duration at overload (110 per cent of the rated output) may be considered.

12.2.5 LR reserves the right to limit the duration of validity of approval of a mass produced turbo-charger. LR is to be informed, without delay, of any change in the design of the turbo-charger, in the manufacturing or control processes, in the selection of materials or in the list of subcontractors for main parts.

12.3 Continuous inspection of individual units

12.3.1 LR Surveyors are to be provided with free access to the manufacturer's workshop to inspect at random the quality control measures and to witness the tests required by 12.3.3 to 12.3.7 as deemed necessary, and to have free access to all control records and subcontractor's certificates.

12.3.2 Each individual unit is to be tested in accordance with 12.3.4 to 12.3.7 by the maker who is to issue a final certificate.

12.3.3 Rotating parts of the turbo-charger blower are to be marked for easy identification with the appropriate certificate.

12.3.4 Material tests of the rotating parts are to be carried out by the maker or his subcontractor in accordance with the requirements of the Rules for Materials as applicable. The relevant certificate is to be produced and filed to the satisfaction of the Surveyor.

12.3.5 Pressure tests are to be carried out in accordance with Table 2.2.1. Special consideration will be given where design or testing features may require modification of the test requirements.

12.3.6 Dynamic balancing and overspeed tests are to be carried out, *see* Pt 9, Ch 2,3.2 and 3.3, in accordance with the approved procedure for quality control. If each forged wheel is individually controlled by an approved non-destructive examination method, then no overspeed test may be required except for wheels of the test unit.

12.3.7 A mechanical running test, *see* Pt 9, Ch 2,3.4, is to be carried out. The duration of the running test may be reduced to 10 minutes provided that the manufacturer is able to verify the distribution of defects established during the running tests on the basis of a sufficient number of tested turbo-chargers. For manufacturers who have facilities in their works for testing the turbo-chargers on an engine for which the turbo-chargers are intended, the bench test may be replaced by a test run of 20 minutes at overload (110 per cent of the rated output) on this engine.

12.4 Compliance and certificate

12.4.1 For every turbo-charger unit liable to be installed on an engine intended for a ship classed by LR, the manufacturer is to supply a statement certifying that the turbo-charger is identical with one that underwent the tests specified in 12.2.4 and that prescribed tests were carried out. Results of these tests are also to be stated. This statement is to be made on a form agreed with LR and a copy is to be sent to LR. Each statement must have a number which is to appear on the turbo-charger.

■ *Section 13*
Electronically controlled engines

13.1 Scope

13.1.1 The requirements of this Section are applicable to engines for propulsion, auxiliary and emergency power purposes with software-based electronic control of fuel, air and exhaust systems.

13.1.2 These engines may be of the slow, medium or high-speed type. They generally have no camshaft to drive fuel, air and exhaust systems, but have common rail fuel/hydraulic arrangements and hydraulic actuating systems for the functioning of the fuel, air and exhaust systems.

13.1.3 The operation of these engines relies on the effective monitoring of a number of parameters such as crank angle, engine speed, temperatures and pressures using one or more electronic control systems to provide the services essential for the operation of the engine such as fuel injection, air inlet, exhaust and speed control.

13.1.4 Deviation from Rule requirements are to be submitted and will be considered on the basis of technical justification by the engine builder.

13.1.5 During the life of the engine any changes to hardware, software, control and monitoring systems which may affect the safety and reliable operation of the engine are to be submitted and approved by LR.

13.2 Plans and particulars

13.2.1 In addition to the plans and particulars required by Section 2 the following information is to be submitted:

(a) A general overview of the operating principles, supported by schematics explaining the functionality of individual systems and sub-systems. The information is to relate to the engine capability and functionality under defined operating and emergency conditions such as recovery from a failure or malfunction, with particular reference to the functioning of electronic control systems and any sub-systems. The information is also to indicate if the engine has different modes of operation, such as to limit exhaust gas emissions and/or to run under an economic fuel consumption mode or any other mode that can be controlled by electronic control systems.

(b) Details of hydraulic systems for actuation of sub-systems (fuel injection, air inlet and exhaust), to include details of the design/construction of pipes, pumps, valves, accumulators and the control of valves/pumps. Details of pump drive arrangements are also to be included.

(c) Failure Modes and Effects Analysis (FMEA) of the mechanical, pressure containing and electrical systems and arrangements that support the operation of the engine. The analysis is to demonstrate that suitable risk mitigation has been achieved so that a system will tolerate a single failure in equipment or loss of an associated sub-system such that operation of the engine will not be lost or degraded beyond acceptable performance criteria of the engine. *See* 13.5.

(d) A schedule of testing and trials to demonstrate that the engine is capable of operating as described in the design statement, and any testing required to verify the conclusions of the FMEA.
(e) Operating manuals which describe the particulars of each system and, together with maintenance instructions, include reference to the arrangements for making modifications and changes to electronic control systems and for the functioning of sub-systems.
(f) Quality plan for sourcing, design, installation and testing of all components used in the oil fuel and hydraulic oil systems installed with the engine for engine operation.
(g) Fatigue analysis for all high pressure oil fuel and hydraulic oil piping arrangements required for engine operation where failure of the pipe or its connection or a component would be the cause of engine unavailability. The analysis is to concentrate on high pressure components and sub-systems and recognise the pressures and fluctuating stresses that the pipe system may be subject to in normal service.
(h) Schedule of testing at engine builders, pre-sea trial commissioning and sea trials. The test schedules are to identify all modes of engine operation and the sea trials are to include typical port manoeuvres under all intended engine operating modes.
(j) Evidence of type testing of the engine with electronic controls, or a proposed test plan at the engine builders with the electronic controls functioning, to verify the functionality and behaviour under fault conditions of the electronic control system.

13.2.2 In addition to the plans and particulars required by Pt 16, Ch 1 the following information for control, alarm, monitoring and safety systems relating to the operation of an electronically controlled engine is to be submitted:
(a) System requirements specification.
(b) Description of operation with explanatory diagrams.
(c) Line diagrams of control circuits.
(d) List of monitored points.
(e) List of control points.
(f) List of alarm points.
(g) List of safety functions and details of any overrides, including consequences of use.
(h) Details of hardware configuration.
(j) Hardware certification details.
(k) Software quality plan.
(l) System integration plan.
(m) Failure Mode and Effects Analysis (FMEA). *See* Pt 10, Ch 1,2.1.6.
(n) Factory acceptance, integration, harbour and sea trials/ test schedules for hardware and software.
(o) Software certification details.
(p) Quality plan for sourcing, design installation and testing of all components used in the control, alarm, monitoring and safety systems installed with the engine for engine operation.

13.3 Oil fuel and hydraulic oil systems

13.3.1 Oil fuel and hydraulic oil piping system arrangements are to comply with Part 15 as applicable.

13.3.2 Where pumps are essential for engine operation, not less than two oil fuel and two hydraulic oil pressure pumps are to be provided for their respective service and arranged such that failure of one pump does not render the other inoperative. Each oil fuel pump and hydraulic oil pump is to be capable of supplying the quantity of oil for engine operation at its maximum continuous rating and arranged ready for immediate use.

13.3.3 The oil fuel pressure piping between the oil fuel high pressure pumps and the fuel injectors is to be protected with a jacketed piping system capable of containing oil fuel leakage from a high pressure pipe failure.

13.3.4 The hydraulic oil pressure piping between the high pressure hydraulic pumps and hydraulic actuators is to be protected with a jacketed piping system capable of containing hydraulic oil leakage from a high pressure pipe failure.

13.3.5 Accumulators and associated high pressure piping are to be designed, manufactured and tested in accordance with a standard applicable to the maximum pressure and temperature rating of the system.

13.3.6 All valves, cocks and screwed connections are to be of a type-tested type applicable to the maximum service conditions anticipated in normal service.

13.3.7 Isolating valves and cocks are to be located as near as practicable to the equipment to be isolated. All valves forming part of the oil fuel and hydraulic oil installation are to be capable of being controlled from readily accessible positions above the working platform.

13.3.8 High pressure oil fuel and high pressure hydraulic oil piping systems are to be provided with high pressure alarms with set points that do not exceed the system design pressures.

13.3.9 High pressure oil fuel and high pressure hydraulic piping systems are to be provided with suitable relief valves on any part of the system that can be isolated and in which pressure can be generated. The settings of the relief valves are not to exceed the design pressures. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressures.

13.3.10 Equipment fitted for monitoring pressures and temperatures in the high pressure oil fuel and high pressure hydraulic oil systems is to comply with a recognised standard suitable to the anticipated vibration and temperature conditions.

13.3.11 A fatigue analysis is to be carried out in accordance with a standard applicable to the system under consideration and all anticipated pressure, pulsation and vibration loads are to be addressed. The analysis is to demonstrate that the design and arrangements are such that the likelihood of failure is as low as reasonably practicable. The analysis is to identify all assumptions made and standards to be applied during manufacture and testing of the system. Any potential weak points which may develop due to incorrect construction or assembly are also to be identified.

13.3.12 For high pressure oil containing and mechanical power transmission systems, the quality plan for sourcing, design, installation and testing of components is to address the following issues:

(a) Design and manufacturing standard(s) applied.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during manufacture and testing.
(d) Details of type approval, type testing or approved type status assigned to the machinery or equipment.
(e) Details of installation and testing recommendations for the machinery or equipment.

13.4 Electronic control systems

13.4.1 Plans and details of electronic control systems are to comply with Pt 16, Ch 1 and Ch 2 as applicable.

13.4.2 For electronic control systems and electrical actuating systems, the quality plan for sourcing, design, installation and testing of components is to address the following issues:

(a) Standard(s) applied.
(b) Details of the quality control system applied during manufacture and testing.
(c) Details of type approval, type testing or approved type status assigned to the equipment.
(d) Details of installation and testing recommendations for the equipment.
(e) Details of any local and/or remote diagnostic arrangements where assessment and alteration of control parameters can be made which can affect the operation of the engine.
(f) Details of arrangements for software upgrades.

13.4.3 The system integration plan is required to identify the process for verification of the functional outputs from the electronic control systems with particular reference to system integrity, consistency, security against unauthorised changes to software and maintaining the outputs within acceptable tolerances for safe and reliable operation of the engine within stated performance criteria.

13.5 FMEA analysis

13.5.1 A Failure Mode and Effects Analysis (FMEA) is to demonstrate that a failure of the functioning of an electronic control system:

(a) Will not result in the loss of the ability to provide the services essential for the operation of the engine (*see* Pt 16, Ch 1,2.5.11 and 2.12.2);
(b) Will not affect the normal operation of the services essential for the operation of the engine other than those services dependent upon the failed part (*see* Pt 16, Ch 1,2.12.4 and 2.12.5); and
(c) Will not leave either the engine, or any equipment or machinery associated with the engine, or the ship in an unsafe condition (*see* Pt 16, Ch 1,2.3.12, 2.4.6, 2.5.5, 2.10.3 and 2.12.5).

13.5.2 Where FMEA analysis is required to be carried out the reports submitted are to address the following issues:

(a) Identify the standards used for analysis and system design.
(b) Identify the objectives of the analysis.
(c) Identify any assumptions made in the analysis.
(d) Identify the equipment, system or sub-system, mode of operation and the equipment.
(e) Identify potential failure modes and their causes.
(f) Evaluate the local effects (e.g. fuel injection failure) and the effects on the system as a whole (e.g. loss of propulsion power) of each failure mode.
(g) Identify measures for reducing the risks associated with each failure mode. This may be through system design, provision of redundant systems and/or quality control procedures for sourcing, manufacture and testing.
(h) Identify trials and testing necessary to prove conclusions.

13.5.3 At sub-system level it is acceptable to consider failure of equipment items and their functions, e.g. failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed, and failure need only be dealt with as a cause of failure of the pump.

13.5.4 In an electronically controlled engine it is necessary to define the essential services on which the operation of the engine relies and the control functions, alarm functions and safety functions for the equipment and machinery providing these services. Examples of essential services are:

(a) Starting arrangements.
(b) Fuel supply arrangements.
(c) Lubricating oil arrangements.
(d) Hydraulic oil arrangements.
(e) Cooling arrangements.
(f) Power supply arrangements.

■ *Section 14* Programme for trials of diesel engines to assess operational capability

14.1 Works trials (acceptance test)

14.1.1 Diesel engines which are to be subjected to trials on the test bed at the manufacturer's works and under attendance by the Surveyor(s) are to be tested in accordance with the scope of works trials specified in 14.1.2 to 14.1.9. The scope of the trials is to be agreed between the LR Surveyor and the manufacturer prior to testing. At the discretion of the Surveyor, the scope of the trials may be extended depending on the engine application.

14.1.2 For all stages of the works trials, the pertaining operation values are to be measured and recorded by the engine manufacturer. All results are to be compiled in an acceptance protocol to be issued by the engine manufacturer.

14.1.3 In each case given in Table 1.14.1, all measurements conducted at the various load points shall be carried out at steady operating conditions. The readings for 100 per cent power (rated power at rated speed) are to be taken twice at an interval of at least 30 minutes.

14.1.4 The data to be measured and recorded, when testing the engine at various load points, are to include all necessary parameters for the engine operation. The crankshaft deflection is to be checked when this check is required by the manufacturer during the operating life of the engine. Crankshaft deflection measurements are to be taken before (cold condition) and after (hot condition) works acceptance trials.

14.1.5 Checks of components to be presented for inspection after the works trials are left to the discretion of the Surveyor.

14.1.6 The Surveyor may require that after the trials the fuel delivery system is restricted so as to limit the engines to run at not more than 100 per cent power. The setting of the restriction is to be made as applicable to the intended fuel. Any restriction settings, and other changes to the engine's fuel injection equipment required for operation on special fuels, are to be recorded and included by the engine manufacturer.

14.1.7 For the duration of the acceptance test, no interventions or adjustments will be made to the machinery under test.

14.1.8 The testing of exhaust gas emissions is to comply with MARPOL as applicable.

14.1.9 For all stages that the engine is to be tested and where no duration is specified in Table 1.14.1, the load point is to be maintained for a sufficient period to allow pertaining values to be measured and recorded when the engine has achieved a steady operating condition.

Table 1.14.1 Scope of works trials for diesel engines

Main engines driving propellers and waterjets		
Trial condition	Duration	Note
100 per cent power (rated power) at rated engine speed, *R*	≥ 60 minutes	After having reached steady conditions
110 per cent power at engine speed corresponding to 1,032**R*	30–45 minutes	After having reached steady conditions (1)
90 per cent (or maximum continuous power), 75 per cent, 50 per cent and 25 per cent	—	Powers in accordance with the nominal propeller curve
Starting and reversing manoeuvres	—	—
Testing of governor and independent overspeed protective device	—	*See* 9.2
Shut down device	—	*See* 9.4
Engines driving generators		
Trial condition	Duration	Note
100 per cent power (rated power) at rated engine speed, *R*	≥ 50 minutes	After having reached steady conditions (2)
110 per cent power	15 minutes	After having reached steady conditions (2) (3)
75 per cent, 50 per cent and 25 per cent power and idle run	—	(2)
Start-up tests	—	—
Testing of governor and independent overspeed protective device	—	*See* 9.3
Shut-down device	—	*See* 9.4

NOTES
1. After running on the test bed, the fuel delivery system of main engines is normally to be so adjusted that overload power cannot be given in service.
2. The test is to be performed at rated speed with a constant governor setting.
3. After running on the test bed, the fuel delivery system of diesel engines driving generators must be adjusted such that overload (110 per cent) power can be given in service after installation on board, so that the governing characteristics including the activation of generator protective devices can be fulfilled at all times.

Table 1.14.2 Scope of shipboard trials for diesel engines

Main engines driving fixed-pitch propellers (1) (2)		
Trial condition	Duration	Note
At rated engine speed, *R*	≥ 4 hours	—
At engine speed corresponding to normal continuous power	≥ 2 hours	—
At engine speed corresponding to 1,032**R*	30 minutes	Where the engine adjustment permits, *see* 14.1.6
At minimum on-load speed	—	—
Starting and reversing manoeuvres	—	*See* Pt 10, Ch 1,7
In reverse direction of propeller rotation during the dock or sea trials at a minimum engine speed of 0,7**R*	10 minutes	—
Monitoring, alarms and safety systems	—	—
Where imposed, test to ensure engine can pass safely through barred speed range	—	—
Engines driving generators for propulsion		
Trial condition	Duration	Note
100 per cent power (rated power), *see* 14.2.3	≥ 4 hours	(3) (4)
At normal continuous power	≥ 2 hours	(3) (4)
In reverse direction of propeller rotation at a minimum speed of 70 per cent of the nominal propeller speed	10 minutes	(3) (4)
Starting manoeuvres	—	—
Monitoring, alarm and safety systems	—	—

NOTES
1. For main propulsion engines driving controllable pitch propellers, waterjets or reversing gears, the tests for main engines driving fixed-pitch propellers apply as appropriate.
2. Controllable pitch propellers are to be tested with various propeller pitches.
3. The tests to be performed at rated speed with a constant governor setting.
4. Tests are to be based on the rated electrical powers of the driven generators.

14.2 Shipboard trials

14.2.1 After the conclusion of the running-in programme prescribed by the engine manufacturer, engines are to undergo shipboard trials as specified in Table 1.14.2. The scope of the trials is to be agreed between the LR Surveyor and the Shipyard prior to testing.

14.2.2 Engines driving generators or important auxiliaries are to be subjected to an operational test for at least 4 hours. During the test, the set concerned is required to operate at its rated power for an extended period. It is to be demonstrated that the engine is capable of supplying 100 per cent of its rated power, and in the case of shipboard generating sets, account shall be taken of the times needed to actuate the generator's overload protection system

14.2.3 In addition to 14.2.2, for engines driving generators for electric propulsion motors as well as auxiliaries, an operational test is to be carried out of at least 4 hours duration at a load which corresponds to 100 per cent of the electric propulsion motor(s) rated power. The astern/ahead manoeuvring capability of the propulsion system is to be demonstrated.

14.2.4 The suitability of an engine to burn residual or other special fuels is to be demonstrated, if the machinery installation is arranged to burn such fuels in service. *See also* Pt 16, Ch 1,6.2.1.

14.2.5 At the discretion of the attending Surveyor, the scope of the trials may be expanded in consideration of special operating conditions, such as towing, trawling, etc.

■ *Section 15* Type testing procedure for crankcase explosion relief valves

15.1 Scope

15.1.1 This test procedure identifies standard conditions by which crankcase explosion relief valves intended to be fitted to diesel engines can be tested to demonstrate that they satisfy LR requirements for type testing to a defined standard.

15.1.2 This test procedure is also applicable to explosion relief valves intended for gear cases.

15.1.3 Standard repeatable test conditions have been established using a methane gas and air mixture.

15.1.4 The test procedure is only applicable to explosion relief valves fitted with flame arresters.

15.2 Purpose

15.2.1 The purpose of type testing crankcase explosion relief valves is fourfold:

(a) To verify the effectiveness of the flame arrester.
(b) To verify that the valve closes after an explosion.
(c) To verify that the valve is gas/air tight after an explosion.
(d) To establish the level of over-pressure protection provided by the valve.

15.3 Test facilities

15.3.1 The test facilities for carrying out type testing of crankcase explosion relief valves are to meet the following requirements:

(a) The test facilities where testing is carried out are to be accredited to a National or International Standard for the testing of explosion protection devices.
(b) The test facilities are to be acceptable to LR.
(c) The test facilities are to be equipped so that they can control and record explosion testing in accordance with this procedure.
(d) The test facilities are to have equipment for controlling and measuring a methane gas in air concentration within a test vessel to an accuracy of ± 0,1 per cent.
(e) The test facilities are to be capable of effective point-located ignition of a methane gas in air mixture.
(f) The pressure measuring equipment is to be capable of measuring the pressure in the test vessel in at least two positions, one at the valve and the other at the test vessel centre. The measuring arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test. The result of each test is to be documented by video recording and if necessary, by recording with a heat sensitive camera.
(g) The test vessel for explosion testing is to have documented dimensions that are to be such that its height or length between dished ends is approximately 2 times its diameter but not more than 2,5 times. The internal volume of the test vessel is to be determined from the vessel dimensions that include any standpipe arrangements.
(h) The test vessel for explosion testing is to be provided with a flange for mounting the explosion relief valve in an orientation consistent with how it will be installed in service, i.e., in the vertical plane or the horizontal plane. The flange arrangement is to be made approximately one third of the height or length of the test vessel.
(j) A circular flat plate having the following dimensions is to be provided for fitting between the pressure vessel flange and valve to be tested:
    1. Outside diameter = 2 x *D* where *D* is the outer diameter of the valve top cover. The circular plate is to provide simulation of the crankcase surface.
    2. Internal bore having the same internal diameter as the valve is to be tested.
(k) The test vessel for explosion testing is to have connections for measuring the methane in air mixture in at least two positions, i.e., top and bottom.
(l) The test vessel for explosion testing is to be provided with a means of fitting an ignition source at a position approximately one third the height or length of the vessel, *see* 15.4.3.
(m) The test vessel volume is to be as far as practicable, related to the size of relief valve to be tested. In general, the volume is to correspond to the requirement in 6.3.1 for the free area of explosion relief valve to be not less than 115 cm^2/m^3 of crankcase gross volume, e.g., the testing of a valve having 1150 cm^2 of free area, would require a test vessel with a volume of 10 m^3. In no case is the volume of the test vessel to vary by more than +15 per cent to –10 per cent from the 115 cm^2/m^3 volume ratio.

15.4 Explosion test process

15.4.1 All explosion tests to verify the functionality of crankcase explosion relief valves are to be carried out using an air and methane mixture with a methane concentration of 9,5 per cent ±0,5 per cent. The pressure in the test vessel is to be not less than atmospheric and not exceed 0,2 bar.

15.4.2 The concentration of methane in the test vessel is to be measured at the top and bottom of the vessel and these concentrations are not to differ by more than 0,5 per cent.

15.4.3 The ignition of the methane and air mixture is to be made at a position approximately one third of the height or length of the test vessel opposite to where the valve is mounted.

15.4.4 The ignition is to be made using a 100 joule explosive charge.

15.5 Valves to be tested

15.5.1 The valves used for type testing are to be manufactured and tested in accordance with procedures acceptable to LR and selected from the manufacturer's usual production line for such valves by the LR surveyor witnessing the tests.

15.5.2 For approval of a specific valve size, three valves of that specific size are to be tested. The valves are to have been tested at the manufacturer's works to demonstrate that the opening pressure is in accordance with that agreed by the engine builder and valve manufacturer within a tolerance of ± 20 per cent and that the valve is air tight at a pressure below the opening pressure for at least 30 seconds.

15.5.3 The selection of valves for type testing is to recognise the orientation in which they are intended to be installed on the engine or gear case. Where it is intended that valves be installed in the vertical or near vertical or the horizontal or near horizontal position, then three valves of each size are to be tested for each intended orientation.

15.6 Method

15.6.1 The following requirements are to be satisfied at explosion testing:

(a) The explosion testing is to be witnessed by a LR surveyor where type testing approval is required by LR.

(b) Valves are to be tested in the vertical or horizontal position consistent with the orientation in which they are intended to be installed on an engine or gear case, usually in the vertical position, *see* 15.5.3.

(c) Where valves are to be installed on an engine or gear case with shielding arrangements to deflect the emission of explosion combustion products, the valves are to be tested with the shielding arrangements fitted.

(d) Type testing is to be carried out for each range of valves for which a manufacturer requires LR approval.

(e) Successive explosion testing to establish a valve's functionality is to be carried out as quickly as possible during stable weather conditions.

(f) The pressure rise and decay during all explosion testing is to be recorded.

(g) The external condition of the valves is to be monitored during each test. The test facility is to produce a report on the explosion test findings.

15.6.2 The explosion testing is to be in three stages for each valve that is required to be approved as being type tested.

15.6.3 **Stage 1.** Two explosion tests are to be carried out with the flange opening fitted with the circular plate covered by a 0,05 mm thick polythene film. These tests establish a reference pressure level for determination of the effects of a relief valve in terms of pressure rise in the test vessel, *see* 15.7.1(f).

15.6.4 **Stage 2.**

(a) Two explosion tests are to be carried out on three different valves of the same size. Each valve is to be mounted in the orientation for which approval is sought, i.e., in the vertical or horizontal position with the circular plate described in 15.3.1(j) located between the valve and pressure vessel mounting flange.

(b) The first of the two tests on each valve is to be carried out with a 0,05 mm thick polythene bag, having a minimum diameter of three times the diameter of the circular plate and volume not less than 30 per cent of the test vessel, enclosing the valve and circular plate. Before carrying out the explosion test the polythene bag is to be empty of air. The polythene bag is required to provide a readily visible means of assessing whether there is flame transmission through the relief valve following an explosion.

(c) Provided that the first explosion test successfully demonstrated that there was no indication of combustion outside the flame arrester and there are no signs of damage to the flame arrester or valve, a second explosion test without the polythene bag arrangement is to be carried out. During the second explosion test, the valve is to be visually monitored for any indication of combustion outside the flame arrester. The second test is required to demonstrate that the valve can still function in the event of a secondary crankcase explosion.

(d) After each explosion, the test vessel is to be maintained in the closed condition for at least 10 seconds to enable the tightness of the valve to be ascertained. The tightness of the valve can be verified during the test from the pressure/time records or by a separate test after completing the second explosion test.

15.6.5 **Stage 3.** Carry out two further explosion tests as described in Stage 1. These further tests are required to provide an average baseline value for assessment of pressure rise, recognising that the test vessel ambient conditions may have changed during the testing of the explosion relief valves in Stage 2.

15.7 Assessment

15.7.1 Assessment of the valves after explosion testing is to address the following:

(a) The valves to be tested are to have evidence of appraisal/approval by LR, *see also* 15.5.1.

(b) The designation, dimensions and characteristics of the valves to be tested are to be recorded. This is to include the free area of the valve and of the flame arrester, and the amount of valve lift at 0,2 bar.

(c) The test vessel volume is to be determined and recorded.

(d) For acceptance of the functioning of the flame arrester there is not to be any indication of flame or combustion outside the valve during an explosion test.

(e) The pressure rise and decay during an explosion is to be recorded, with indication of the pressure variation showing the maximum overpressure and steady underpressure in the test vessel during testing. The pressure variation is to be recorded at two points in the pressure vessel.

(f) The effect of an explosion relief valve in terms of pressure rise following an explosion is ascertained from maximum pressures recorded at the centre of the test vessel during the three stages. The pressure rise within the test vessel due to the installation of a relief valve is the difference between average pressure of the four explosions from Stages 1 and 3 and the average of the first tests on the three valves in Stage 2.
(g) The valve tightness is to be ascertained by verifying from records that an underpressure of at least 0,3 bar is held by the test vessel for at least 10 seconds following an explosion.
(h) After each explosion test in Stage 2, the external condition of the flame arrester is to be examined for signs of damage and/or deformation.
(j) After completing the explosion tests, the valves are to be dismantled and the condition of all components ascertained and documented. In particular, any indication of valve sticking or uneven opening is to be noted. Photographic records of the valve condition are to be taken and included in the report.

15.8 Design series qualification

15.8.1 The qualification of quenching devices to prevent the passage of flame can be evaluated for other similar devices of identical type where one device has been tested and found satisfactory.

15.8.2 The quenching ability of a flame screen depends on the total mass of quenching lamellas/mesh. Provided the materials, thickness of materials, depth of lamellas/thickness of mesh layer and the quenching gaps are the same, then the same quenching ability can be qualified for different size of flame arresters subject to (a) and (b) being satisfied.

(a) $$\frac{n_1}{n_2} = \sqrt{\frac{S_1}{S_2}}$$

(a) $$\frac{A_1}{A_2} = \frac{S_1}{S_2}$$

where
n_1 = number of lamellas of size 1 quenching device for a valve with a relief area equal to S_1
n_2 = number of lamella of size 2 quenching device for a valve with a relief area equal to S_2
A_1 = free area of quenching device for a valve with a relief area equal to S_1
A_2 = free area of quenching device for a valve with a relief area equal to S_2.

15.9 The Report

15.9.1 The test facility is to deliver a full report that includes the following information and documents:
(a) Test specification.
(b) Details of test pressure vessel and valves tested.
(c) The orientation in which the valve was tested (vertical or horizontal position).
(d) Methane in air concentration for each test.
(e) Ignition source.
(f) Pressure curves for each test.
(g) Video recordings of each valve test.

15.10 Approval

15.10.1 Approval of an explosion relief valve is the prerogative of LR, based on the appraisal of plans and particulars and the test facility's report of the results of type testing.

■ *Section 16*
Type testing procedure for crankcase oil mist detection/monitoring and alarm arrangements

16.1 Scope

16.1.1 This test procedure identifies standard conditions by which crankcase oil mist detection/monitoring and alarm equipment and systems intended to be fitted to diesel engines can be tested to demonstrate that they satisfy LR requirements for type testing to a defined standard.

16.1.2 This test procedure is also applicable to oil mist detection/monitoring and alarm arrangements intended for gear cases.

16.2 Purpose

16.2.1 The purpose of type testing crankcase oil mist detection/monitoring and alarm arrangements is sevenfold:
(a) To verify the functionality of the system.
(b) To verify the effectiveness of the oil mist detectors.
(c) To verify the accuracy of the oil mist detectors.
(d) To verify the alarm set points.
(e) To verify time delays between mist extraction from crankcase and alarm activation.
(f) To verify the operation of alarms to indicate functional failure in the equipment and associated arrangements.
(g) To verify that there is an indication when optical obscuration has reached a level that will affect the reliability of information and alarms.

16.3 Test facilities

16.3.1 The test house carrying out type testing of crankcase oil mist detection/monitoring and alarm equipment and arrangements is to satisfy the following criteria:
(a) The test facilities are to have the full range of facilities for carrying the type and functionality tests required by this procedure and be acceptable to LR.
(b) The test house that verifies that the equipment ascertains the levels of oil mist concentration is to be equipped so that it can control, measure and record oil mist concentration levels in terms of mg/l to an accuracy of ±10 per cent in accordance with this procedure.
(c) The type tests are to be witnessed by an LR Surveyor unless otherwise agreed.

(d) The oil mist concentrations are to be ascertained by the gravimetric deterministic method or equivalent. The gravimetric deterministic method is a laboratory process where the difference in weight of a millipore (typically 0,8 μm) filter is ascertained by weighing the filter before and after drawing 1*d* m^3 of oil mist through the filter.
(e) The results of a gravimetric analysis are considered invalid and are to be rejected if the resultant calibration curve has an increasing gradient with respect to the oil mist detection/monitoring reading. This situation occurs when insufficient time has been allowed for the oil mist to become homogeneous. Single results that are more than 10 per cent below the calibration curve are to be rejected. This situation occurs when the integrity of the filter unit has been compromised and not all of the oil is collected on the filter paper.
(f) The filters are required to be weighed to a precision of 0,1 mg and the volume of air/oil mist sampled to a precision of 10 ml.

16.4 Equipment testing

16.4.1 The range of tests is to include the following for the alarm/monitoring panel:
(a) Functional tests described in 16.5.
(b) Electrical power supply failure test.
(c) Power supply variation test.
(d) Dry heat test.
(e) Damp heat test.
(f) Vibration test.
(g) EMC test.
(h) Insulation resistance test.
(j) High voltage test.
(k) Static and dynamic inclinations, if moving parts are contained.

16.4.2 The range of tests is to include the following for the detectors:
(a) Functional tests described in 16.5.
(b) Electrical power supply failure test.
(c) Power supply variation test.
(d) Dry heat test.
(e) Damp heat test.
(f) Vibration test.
(g) Insulation resistance test.
(h) High voltage test.
(j) Static and dynamic inclinations, if moving parts are contained.

16.5 Functional test process

16.5.1 All tests to verify the functionality of crankcase oil mist detection/monitoring devices are to be carried out in accordance with 16.5.2 to 16.5.6 with an oil mist concentration in air, known in terms of mg/l to an accuracy of ±10 per cent.

16.5.2 The concentration of oil mist in the test vessel is to be measured in the top and bottom of the vessel and these concentrations are not to differ by more than 10 per cent.

16.5.3 The oil mist monitoring arrangements are to be capable of detecting oil mist in air concentrations of between 0 and 10 per cent of the lower explosive limit (LEL), which corresponds to an oil mist concentration of approximately 50 mg/l (15 per cent oil-air mixture).

16.5.4 The operation of the alarm indicators for oil mist concentration in air are to be verified and are to provide an alarm at a maximum setting corresponding to 5 per cent of the LEL or approximately 2.5mg/l.

16.5.5 Where alarm set points can be altered, the means of adjustment and indication are to be verified against the equipment manufacturer's instructions.

16.5.6 Where oil mist is drawn into a detector/monitor via piping arrangements, the time delay between the sample leaving the crankcase and operation of the alarm is to be determined for the longest and shortest lengths of pipes recommended by the manufacturer. The pipe arrangements are to be in accordance with the manufacturer's instructions/ recommendations.

16.6 Detectors/monitors and equipment to be tested

16.6.1 The detectors/monitors and equipment used in type testing are to be manufactured and tested in accordance with procedures acceptable to LR and selected from the manufacturer's usual production line for such equipment by the LR Surveyor witnessing the tests.

16.6.2 Two sets of detectors/monitors requiring approval are to be tested. One set is to be tested in the clean condition and the other in a condition that represents the maximum degree of lens obscuration that is stated as being acceptable by the manufacturer.

16.7 Method

16.7.1 The following requirements are to be satisfied at type testing:
(a) The testing is to be witnessed by a LR Surveyor where type testing approval is required by LR.
(b) Oil mist detection/monitoring devices are to be tested in the orientation in which they are intended to be installed on an engine or gear case.
(c) Type testing is to be carried out for each range of oil mist detection/monitoring devices that a manufacturer requires LR approval.
(d) The test house is to produce a test report.

16.8 Assessment

16.8.1 Assessment of oil mist detection/monitoring devices after testing is to address the following:

(a) The devices to be tested are to have evidence of appraisal/approval by LR, *see also* 16.6.1.

(b) The details of the detection/monitoring devices to be tested are to be recorded. This is to include manufacturer, type designation, oil mist concentration assessment capability and alarm settings.

(c) After completing the tests, the detection/monitoring devices are to be examined and the condition of all components ascertained and documented. Photographic records of the monitoring devices condition are to be taken and included in the report.

16.9 Design series qualification

16.9.1 The approval of one detection/monitoring device may be used to qualify other devices having identical construction details. Proposals are to be submitted for consideration.

16.10 The Report

16.10.1 The test house is to provide a full report which includes the following information and documents:

(a) Test specification.

(b) Details of devices tested.

(c) Results of tests.

16.11 Acceptance

16.11.1 Acceptance of crankcase oil mist detection/monitoring devices is the prerogative of LR, based on the appraisal of plans and particulars and the test house report of the results of type testing.

16.11.2 The following information is to be submitted to LR for acceptance of oil mist detection/monitoring and alarm arrangements:

(a) Description of oil mist detection/monitoring equipment and system including alarms.

(b) Copy of the test house report identified in 16.10.

(c) Schematic layout of engine oil mist detection/monitoring arrangements showing location of detectors/sensors and piping arrangements and dimensions.

(d) Maintenance and test manual which is to include the following information:
- Intended use of equipment and its operation.
- Functionality tests.
- Maintenance routines and spare parts recommendations.
- Limit setting and instructions for safe limit levels.
- Where necessary, details of configurations in which the equipment is and is not to be used.

■ *Section 1*
General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 The requirements of this Chapter are applicable to gas turbines for main propulsion and essential auxiliary services.

1.2 Power ratings

1.2.1 In this Chapter, where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in Part 9.

1.3 Power conditions for generator sets

1.3.1 Auxiliary gas turbines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output and of developing for a short period (15 minutes) an overload power of not less than 10 per cent, *see* Pt 16, Ch 2.

1.4 Inclination of craft

1.4.1 Main and essential auxiliary gas turbines are to operate satisfactorily under the conditions as shown in Table 1.4.1 in Pt 9, Ch 1.

■ *Section 2*
Particulars to be submitted

2.1 Plans and information

2.1.1 At least three copies of the following plans are to be submitted:
- Sectional assembly.
- Casings.
- Combustion chambers and heat exchangers.
- Rotors, bearings and couplings.
- Blades and blade attachments.
- Inlet and exhaust ducting.
- Securing arrangement (including details of resilient mounts where applicable).
- Control engineering aspects in accordance with Pt 16, Ch 1.
- Fuel oil system schematic, including controls and safety devices.
- Lubricating oil system schematic.
- Starting system schematic.
- Cooling water system schematic, where applicable.

2.1.2 The following information and calculations are to be submitted:

(a) Details of the acoustic enclosure fire detection and extinguishing system, where applicable.

(b) Power/speed operational envelope.
Calculations and information for short term high power operation, where applicable.
Operation and Maintenance Manuals.

(c) Calculations of the critical speeds of blade and rotor vibration, giving full details of the basic assumptions.
An analysis of the effect of a rotor blade failure and any details of service experience, *see* 4.3.

(d) High temperature characteristics of the materials, where applicable, including (at the working temperatures) the associated creep rate and rupture strength for the designed service life, fatigue strength, corrosion resistance and scaling properties.
Particulars of heat treatment, including stress relief, where applicable.
Material specifications covering the listed components together with details of any surface treatments, non-destructive testing and hydraulic tests.

2.1.3 The most onerous pressures and temperatures to which each component may be subjected are to be indicated on plans or provided as part of the design specification.

2.1.4 Calculations of the steady state stresses, including the effect of stress raisers, etc., in the turbine and compressor rotors and blading at the maximum speed and temperature in service are to be submitted. Such calculations should indicate the designed service life and be accompanied, where possible, by test results substantiating the limiting criteria.

2.1.5 Details of calculations and tests to establish the service life of other stressed parts, including gearing (where applicable), bearings, seals, etc., are also to be submitted. All calculations and tests should take account of all relevant environmental factors including particular type of service and fuel intended to be used.

2.1.6 Components fabricated by means of welding will be considered for acceptance if constructed by firms whose works are properly equipped to undertake welding of the standards appropriate to the components. Details are to be submitted for consideration.

2.1.7 Before work is commenced, manufacturers are to submit for consideration details of proposed welding procedures and their proposals for routine examination of joints by non-destructive means.

2.1.8 The manufacturer's proposals for testing the gas turbine are to be submitted for consideration.

2.1.9 A Failure Mode and Effects Analysis (FMEA) is to be submitted as detailed in Part 9.

■ *Section 3* Materials

3.1 Materials for forgings

3.1.1 Rotors and discs are to be of forged steel. For carbon and carbon-manganese steel forgings, the specified minimum tensile strength is to be selected within the limits of 400 and 600 N/mm^2. For alloy steel rotor forgings, the specified minimum tensile strength is to be selected within the limits of 500 and 800 N/mm^2. For discs and other alloy steel forgings, the specified minimum tensile strength is to be selected within the limits of 500 and 1000 N/mm^2. *See also Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 For alloy steels, specifications giving the proposed chemical composition and heat treatment are to be submitted for approval.

3.1.3 When it is proposed to use a material of higher tensile strength, full details are to be submitted for approval.

3.1.4 Components of non-ferrous construction should be submitted for consideration, together with full details of materials to be used and method of fabrication.

3.2 Material tests and inspection

3.2.1 Components are to be tested in accordance with the relevant requirements of the Rules for Materials.

3.2.2 For components of novel design special consideration will be given to the material test and non-destructive testing requirements.

■ *Section 4* Design

4.1 General

4.1.1 All parts of turbines, compressors, etc., are to have clearances and fits consistent with adequate provision for the relative thermal expansion of the various components. Special attention is to be given to minimizing casing and rotor distortion under all operating conditions.

4.1.2 Turbine bearings are to be so disposed and supported that lubrication is not adversely affected by heat flow from adjacent hot parts. Effective means are to be provided for intercepting oil leakage and preventing oil from reaching high temperature glands and casings.

4.2 Vibration

4.2.1 Care is to be taken in the design and manufacture of turbine and compressor rotors, rotor discs and rotor blades to ensure freedom from undue vibration within the operating speed range. Where critical speeds are found by calculation to occur within the operating speed range, vibration measurements may be requested in order to verify the calculations, *see* Part 13.

4.3 Containment

4.3.1 Gas turbines are to be designed and installed so as to contain debris in the event of an internal failure.

4.3.2 The gas turbine is to be located such that any flying debris resulting from a failure will not endanger the craft, other machinery, occupants of the craft or any other persons.

4.3.3 Where an acoustic enclosure is fitted which completely surrounds the gas generator and the high pressure oil pipes, a fire detection and extinguishing system is to be provided for the acoustic enclosure.

4.4 External influences

4.4.1 Pipes and ducting connected to casings are to be so designed that no excessive thrust loads or moments are applied by them to the compressors and turbines.

4.4.2 Platform gratings and fittings in way of the supports are to be so arranged that casing expansion is not restricted.

4.4.3 Where main turbine seatings incorporating a tank structure are proposed, consideration is to be given to the temperature variation of the tank in service to ensure that turbine alignment will not be adversely affected.

4.4.4 For securing arrangements, including resilient mounting, *see* Pt 9, Ch 1.

Section 5
Construction

5.1 Welded components

5.1.1 Major joints are to be designed as full-strength welds and for complete fusion of the joint.

5.1.2 Stress relief heat treatment is to be applied to all cylinders, rotors and associated components on completion of the welding of all joints and attached structures, *see* Part 15.

Section 6
Starting arrangements

6.1 Initial starting arrangements

6.1.1 Equipment for starting main and auxiliary turbines is to be provided and arranged such that the necessary initial charge of starting air or initial electric power can be developed on board the craft without external aid. If for this purpose an emergency air compressor or electric generator is required, these units are to be power driven by manually started oil engines except in the case of small installations where a hand operated compressor of approved capacity may be accepted. Alternatively, other devices of approved type may be accepted as a means of providing the initial start, *see also* Pt 16, Ch 2,2.4.2.

6.2 Purging before ignition

6.2.1 Means are to be provided, preferably automatic or interlocked, to clear all parts of the gas turbine of the accumulation of oil fuel or for purging gaseous fuel before ignition commences on starting, or recommences after failure to start. The purge is to be of sufficient duration to displace at least three times the volume of the exhaust system.

6.3 Air starting

6.3.1 Where the gas turbine is arranged for air starting the total air receiver capacity is to be sufficient to provide, without replenishment, not less than six consecutive starts. At least two air receivers of approximately equal capacity are to be provided. For scantlings and fittings of air receivers, *see* Part 15.

6.3.2 For multi-engine installations three consecutive starts per engine are required.

6.4 Electric starting

6.4.1 Where main turbines are fitted with electric starters, two batteries are to be fitted. Each battery is to be capable of starting the turbines when cold and the combined capacity is to be sufficient without recharging to provide the number of starts of the main turbines as required by 6.3.

6.4.2 Electric starting arrangements for auxiliary turbines are to have two separate batteries or be supplied by separate circuits from the main turbine batteries when such are provided. Where one of the auxiliary turbines only is fitted with an electric starter one battery will be acceptable.

6.4.3 The combined capacity of the batteries for starting the auxiliary turbines is to be sufficient for at least three starts for each turbine.

6.4.4 The requirements for battery installations are given in Pt 16, Ch 2.

Section 7
Piping systems

7.1 General

7.1.1 Gas turbine piping systems are, in general, to comply with the requirements given in Pt 15, Ch 1 and Ch 3, due regard being paid to the particular type of installation.

7.1.2 Synthetic rubber hoses, with single or double closely woven integral wire braid reinforcement, or convoluted metal pipes with wire braid protection, may be used in compressed air, fresh water, sea-water, oil fuel and lubricating oil systems. Where synthetic rubber hoses are used for fuel or supply to burners, the hoses are to have external wire braid protection in addition to the integral wire braid.

7.2 Oil fuel systems

7.2.1 Oil fuel arrangements are to comply with the requirements of Pt 15, Ch 3.

7.2.2 Two or more filters are to be fitted in the oil fuel supply lines to the main and auxiliary turbines, and the arrangements are to be such that any filter can be cleaned without interrupting the supply of filtered oil fuel to the turbines.

7.3 Lubricating oil systems

7.3.1 Lubricating oil arrangements are to comply with the requirements of Pt 15, Ch 3.

7.3.2 Where the lubricating oil for main propelling gas turbines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the turbine or reducing the supply of filtered oil to the turbine.

7.4 Cooling systems

7.4.1 Cooling water arrangements are to comply with the requirements of Pt 15, Ch 3, as applicable.

7.5 Inlet and exhaust systems

7.5.1 The air-inlet system is to be designed to minimize the ingestion of harmful particles. Icing up of air intakes is to be prevented.

7.5.2 Means for preventing the accumulation of salt deposits in the compressors and turbines, e.g. water washing, are to be provided.

7.5.3 The arrangement of the exhaust system is to be such as to prevent exhaust gases being drawn into manned spaces, air conditioning systems and air intakes. They should not discharge into air cushion intakes.

7.5.4 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back to the turbine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self draining overboard. Erosion/corrosion resistant shut off flaps or other devices are to be fitted on the hull side shell or pipe end and acceptable arrangements made to prevent water flooding the space.

7.5.5 Where two or more turbines have a common exhaust, an isolating device is to be provided in each exhaust pipe.

7.5.6 The exhaust system is to be arranged so that hot exhaust gases are directed away from areas to which personnel have access, either on board or in the vicinity of where the craft is berthed.

■ *Section 8* Control and monitoring

8.1 General

8.1.1 Control engineering systems are to comply with the requirements of Part 16.

8.2 Overspeed protective devices

8.2.1 An overspeed protective device is to be provided for each shaft of main and auxiliary turbines to automatically shut off the fuel, near the burners, to prevent a dangerous overspeed condition of the shaft, unless it can be established that such a condition cannot arise.

8.2.2 The overspeed device is to be set to operate before the speed of the line exceeds the rated maximum speed by 10 per cent. For auxiliary turbines driving electric generators this setting may be increased to 15 per cent.

8.3 Speed governors

8.3.1 Where a main propulsion installation incorporates a reverse gear, electric transmission or controllable (reversible) pitch propeller, a speed governor, independent of the overspeed protective device, is to be fitted and is to be capable of controlling the speed of the unloaded power turbine without bringing the overspeed protective device into action.

8.3.2 Where an auxiliary turbine is intended for driving an electric generator, a speed governor, independent of the overspeed protective device, is to be fitted which, with fixed setting, is to control the speed within 10 per cent momentary variation and five per cent permanent variation when full load is suddenly taken off or put on. The permanent speed variations of a.c. machines intended for parallel operations are to be equal within a tolerance of ±0,5 per cent.

8.4 Lubricating oil failure

8.4.1 Main turbines are to have an arrangement whereby fuel is automatically shut off, near the burners, in the event of failure of the lubrication system.

8.5 Indication of temperature

8.5.1 Means are to be provided for indicating the temperature of power turbine exhaust gases.

8.6 Automatic and remote controls

8.6.1 Where gas turbines are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarm and safety arrangements required by 8.6.2 and Table 2.8.1 as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

8.6.2 The following turbine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the turbine:

(a) Lubricating oil supply.
(b) Oil fuel supply, *see also* 8.6.3.
(c) Exhaust gas.

8.6.3 The oil fuel supply may be fitted with an automatic control for viscosity instead of the temperature control required by 8.6.2.

8.6.4 A means of manually shutting off the fuel in an emergency is to be provided at the manoeuvring station.

Table 2.8.1 Alarms and safeguards

Item	Alarm	Note
Overspeed	High	Automatic shut down
Lubricating oil pressure for turbine and gearing	1st stage low	
	2nd stage low	Automatic shut down
Lubricating oil temperature	High	
Lubricating oil filter differential pressure	High	
Oil fuel supply pressure	Low	
Oil fuel supply temperature	High	
Bearing temperature	High	
Exhaust gas temperature	1st stage high	
	2nd stage high	Automatic shut down
Turbine vibration	1st stage high	
	2nd stage high	Automatic shut down
Rotor axial displacement	High	Automatic shut down, *see* Note 2
Flame and ignition	Failure	Automatic shut down
Automatic starting	Failure	Automatic shut down
Compressor inlet vacuum	1st stage high	
	2nd stage high	Automatic shut down
Control system	Failure	

NOTES
1. Automatic or interlocked means are to be provided for clearing all parts of the main gas turbine of the accumulation of liquid fuel or for purging gaseous fuel, before ignition commences on starting or recommences after failure to start.
2. Except for gas turbines with rolling element bearings.

■ *Section 9*
Requirements for craft which are not required to comply with the HSC Code

9.1 General

9.1.1 The requirements of Sections 1 to 8 apply to craft which are not required to comply with the HSC Code, unless specifically exempted by the contents of this Section.

9.1.2 The requirements of 1.4.1 do not apply to yachts or service craft less than 24 m.

9.2 Information and calculations

9.2.1 Gas turbines for craft with a power output not exceeding 110 kW do not have to comply with 2.1.2(c) and (d) or 2.1.4 to 2.1.7 inclusive and 2.1.9.

9.3 Starting arrangements

9.3.1 Craft with a Service Group notation of G1 or G2 do not have to comply with 6.1.1.

9.4 Piping systems

9.4.1 Soft solder is not to be used for attaching pipe fittings forming part of oil fuel systems.

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■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 The requirements of this Chapter, except where otherwise stated are applicable to electric motor, gas turbine and diesel engine gearing for driving:

(a) Conventional, totally submerged propeller(s)/impeller(s) for main propulsion purposes, for transmitted powers greater than 220 kW.

(b) Auxiliary machinery which is essential for the safety of the craft or for safety of persons on board where the transmitted powers exceed 110 kW.

1.1.3 Gear designs for applications other than those specified in 1.1.2 will be specially considered.

1.1.4 In any mesh, the terms pinion and wheel refer to the smaller and larger gear respectively.

1.1.5 Bevel gears will be specially considered on the basis of a conversion to equivalent cylindrical gears.

1.1.6 For vibration and alignment requirements, *see* Part 13.

1.2 Power ratings

1.2.1 In this Chapter where the dimensions of any particular components are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in Part 9.

1.3 Inclination of craft

1.3.1 Main and auxiliary gear units are to operate satisfactorily under the conditions as shown in Table 1.4.1 in Pt 9, Ch 1.

■ *Section 2* Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the following plans and information as detailed in 2.2 to 2.3 are to be submitted.

2.2 Plans

2.2.1 **Gearing:**

- Cross sectional views indicating general arrangement.
- Detailed plans of elements.

2.2.2 **Shafting and auxiliary systems:**

- Mass elastic schematic showing gear unit torsional data.
- Arrangements plan indicating bearing positions.
- Detailed plans indicating scantlings of shafts, couplings and bolting.
- Schematic plans of the lubricating oil system, together with pipe material, relief valve and working pressures.
- Schematic of the control and electrical system.

2.3 Information

2.3.1 **Gearing:**

- Operational power/speed envelope for each pinion.
- Number of teeth in each gear.
- Reference diameters.
- Helix angles at reference diameters.
- Normal pitches of teeth at reference diameters.
- Tip diameters.
- Root diameters.
- Face widths and gaps, where applicable.
- Pressure angles of teeth (normal or transverse) at reference diameters.
- Accuracy grade Q in accordance with ISO 1328 or an equivalent standard.
- Surface texture of tooth flanks and roots.
- Minimum backlash.
- Centre distance.
- Basic rack tooth form.
- Protuberance and final machining allowance.
- Details of post hobbing processes, if any.
- Details of tooth flank corrections, if adopted.
- Case depth for surface-hardened teeth.
- Shrinkage allowance for shrunk-on rims and hubs.
- Type of coupling proposed for oil engine applications.
- Details of surface treatment.
- Additional measures, not covered by the Rules, taken during manufacture of the gear elements, to improve the load capacity of the gear teeth.
- Calculations for short term high power operation, where applicable, *see* Part 9.
- Failure mode effects analysis as required by Part 9.
- Specifications for carbon-manganese and alloy steel forging materials of pinions, pinion sleeves, wheel rims, gear wheels, couplings, bolting and all transmission shafting, giving chemical composition, heat treatment and mechanical properties.

2.3.2 **Shafting and auxiliary systems:**

- Details of clutch units, where fitted.
- Details of alarms and control systems, where fitted.
- Schematic plans of the lubricating oil system, together with pipe material, relief valve and working pressures.

■ *Section 3* Materials

3.1 Requirements and specifications

3.1.1 Components for gearboxes are to be in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 Manufacturers' test certificates for forgings may be accepted where the transmitted power does not exceed 220 kW.

3.1.3 In the selection of materials for pinions and wheels, consideration is to be given to their compatibility in operation. Except in the case of low reduction ratios, for gears of through-hardened steels, provision is also to be made for a hardness differential between pinion teeth and wheel teeth. For this purpose, the specified minimum tensile strength of the wheel rim material is not to be more than 85 per cent of that of the pinion.

3.1.4 Gear wheel and rim forgings with a specified minimum tensile strength not in excess of 760 N/mm^2 may be made in carbon-manganese steel. Gear wheel or rim forgings where the specified minimum tensile strength is in excess of 760 N/mm^2, and all pinion or pinion sleeve forgings are to be made in a suitable alloy steel.

3.1.5 Forgings for couplings, quill shafts and gear wheel shafts are to comply with the requirements of Pt 11, Ch 2.

■ *Section 4* Design of gearing

4.1 Symbols

4.1.1 The following symbols apply:

a = centre distance, in mm

b = face width, in mm
NOTE: unless otherwise specified, b is to be taken as the lesser value of b_1 or b_2
In the case of double helical gears $b = 2b_B$ where b_B is the width of one helix

d = reference diameter, in mm

d_a = tip diameter, in mm

d_{an} = virtual tip diameter, in mm

d_b = base diameter, in mm

d_{bn} = virtual base diameter, in mm

d_{en} = virtual diameter to the highest point of single tooth pair contact, in mm

d_f = root diameter, in mm

d_{fn} = virtual root diameter, in mm

d_n = virtual reference diameter, in mm

d_s = shrink diameter, in mm

d_w = pitch circle diameter, in mm

f_{ma} = tooth flank misalignment due to manufacturing errors, in μm

f_{pb} = maximum base pitch deviation of wheel, in μm

f_{Sh} = tooth flank misalignment due to wheel and pinion deflections, in μm

f_{Sho} = intermediary factor for the determination of f_{Sh}

g_α = length of line of action for external gears, in mm:

$$= 0{,}5\sqrt{\left(d_{a1}^2 - d_{b1}^2\right)} + 0{,}5\sqrt{\left(d_{a2}^2 - d_{b2}^2\right)} - a\sin\alpha_{tw}$$

for internal gears:

$$= 0{,}5\sqrt{\left(d_{a1}^2 - d_{b1}^2\right)} - 0{,}5\sqrt{\left(d_{a2}^2 - d_{b2}^2\right)} + a\sin\alpha_{tw}$$

h = total depth of tooth, in mm

h_{ao} = basic rack addendum of tool, in mm

h_F = bending moment arm for root stress, in mm

m_n = normal module, in mm

n = rev/min of pinion

q = machining allowances, in mm

q_s = notch parameter

q' = intermediary factor for the determination of C_γ

u = gear ratio = $\dfrac{\text{Number of teeth in wheel}}{\text{Number of teeth in pinion}} \geq 1$

v = linear speed at pitch circle, in m/s

x = addendum modification coefficient

y_α = running in allowance, in μm

y_β = running in allowance, in μm

z = number of teeth

z_n = virtual number of teeth = $\dfrac{z}{\cos^2\beta_o\cos\beta}$

C_γ = tooth mesh stiffness (mean total mesh stiffness per unit face width), in N/mm μm

F_t = nominal tangential tooth load, in N

$$= \frac{P}{nd}\,19{,}098 \times 10^6$$

F_β = total tooth alignment deviation (maximum value specified), in μm

$F_{\beta x}$ = actual longitudinal tooth flank deviation before running in, in μm

$F_{\beta y}$ = actual longitudinal tooth flank deviation after running in, in μm

HV = Vickers hardness number

K_A = application factor

$K_{F\alpha}$ = transverse load distribution factor

$K_{F\beta}$ = longitudinal load distribution factor

$K_{H\alpha}$ = transverse load distribution factor

$K_{H\beta}$ = longitudinal load distribution factor

K_v = dynamic factor

$K_{v\alpha}$ = dynamic factor for spur gears

$K_{v\beta}$ = dynamic factor for helical gears

K_γ = load sharing factor

P = transmitted power, in kW

P_r = radial pressure at shrinkage surface, in N/mm^2

P_{ro} = protuberance of tool, in mm

Q = accuracy grade from ISO 1328 – 1975

R_a = surface roughness – arithmetical mean deviation (C.L.A.) as determined by an instrument having a minimum wavelength cut-off of 0,8 mm and for a sampling length of 2,5 mm, in µm
S_{pr} = residual undercut left by protuberance in mm
$S_{F\,min}$ = minimum factor of safety for bending stress
S_{Fn} = tooth root chord in the critical section, in mm
$S_{H\,min}$ = minimum factor of safety for Hertzian contact stress
Y_D = design factor
Y_F = tooth form factor
$Y_{R\,rel\,T}$ = relative surface finish factor
Y_S = stress concentration factor
Y_{ST} = stress correction factor
Y_x = size factor
Y_β = helix angle factor
$Y_{\delta\,rel\,T}$ = relative notch sensitivity factor
Z_E = material elasticity factor
Z_H = zone factor
Z_R = surface finish factor
Z_V = velocity factor
Z_X = size factor
Z_β = helix angle factor
Z_ε = contact ratio factor
α_{en} = pressure angle at the highest point of single tooth contact, in degrees
α_n = normal pressure angle at reference diameter, in degrees
α_t = transverse pressure angle at reference diameter, in degrees
α_{tw} = transverse pressure angle at pitch circle diameter, in degrees
$\alpha_{F\,en}$ = angle for application of load at the highest point of single tooth contact, in degrees
β = helix angle at reference diameter, in degrees
β_b = helix angle at base diameter, in degrees
γ = intermediary factor for the determination of f_{Sh}
ε_α = transverse contact ratio

$$= \frac{g\alpha \cos\beta}{\pi\, m_n \cos\alpha_t}$$

$\varepsilon_{\alpha n}$ = virtual transverse contact ratio
ε_β = overlap ratio

$$= \frac{b \sin\beta}{\pi\, m_n}$$

ε_γ = total contact ratio
ρ_{ao} = tip radius of tool, in mm
ρ_c = relative radius of curvature at pitch point, in mm

$$= \frac{a \sin\alpha_{tw}\, u}{\cos\beta_b\,(1 + u)^2}$$

ρ_F = tooth root fillet radius at the contact of the 30° tangent, in mm
σ_y = yield or 0,2 per cent proof stress, in N/mm^2
σ_B = ultimate tensile strength, in N/mm^2
σ_F = bending stress at tooth root, N/mm^2
$\sigma_{F\,lim}$ = endurance limit for bending stress in N/mm^2
σ_{FP} = allowable bending stress at the tooth root, in N/mm^2
σ_H = Hertzian contact stress at the pitch circle, in N/mm^2
$\sigma_{H\,lim}$ = endurance limit for Hertzian contact stress, in N/mm^2
σ_{HP} = allowable Hertzian contact stress, in N/mm^2

Subscript: $_1$ = pinion
$_2$ = wheel
$_0$ = tool

NOTE
a and *z* are considered positive for both external and internal gearing for the purposes of these calculations.

4.2 Tooth form

4.2.1 The tooth profile in the transverse section is to be of involute shape, and the roots of the teeth are to be formed with smooth fillets of radii not less than $0,25m_n$.

4.2.2 All sharp edges left on the tips and ends of pinion and wheel teeth after hobbing and finishing are to be removed.

4.3 Tooth loading factors

4.3.1 For values of application factor, K_A, *see* Table 1.4.1.

Table 1.4.1 Values of K_A

Main and auxiliary gears	K_A
Main propulsion – electric motor or gas turbine, reduction gears	1,15
Main propulsion – diesel engine reduction gears:	
Hydraulic coupling or equivalent on input	1,10
High elastic coupling on input	1,30
Other coupling	1,50
Auxiliary Gears:	
Electric, gas turbine and diesel engine drives with hydraulic coupling or equivalent on input	1,00
Diesel engine drives with high elastic coupling on input	1,20
Diesel engine drives with other couplings	1,40

4.3.2 Load sharing factor, K_γ. When a gear drives two or more mating gears where the total transmitted load is not evenly distributed between the individual meshes, K_γ is to be taken as 1,15, otherwise K_γ is to be taken as 1,0. Alternatively, where measured data exists, a derived value will be considered.

4.3.3 **Dynamic factor, K_v:**

For helical gears with $\varepsilon_\beta \geq 1$:

$$K_v = 1 + Q^2 v z_1 10^{-5} = K_{VB}$$

For helical gears with $\varepsilon_\beta \leq 1$:

$$K_v = K_{va} - \varepsilon_\beta (K_{va} - K_{v\beta})$$

For spur gears:

$$K_v = 1 + 1{,}8\, Q^2 v z_1 10^{-5} = K_{va}$$

where $\dfrac{v z_1}{100} > 14$ for helical gears, and

where $\dfrac{v z_1}{100} > 10$ for spur gears, the value of K_v will be specially considered

NOTE
Q is to be taken as the larger value of Q_1 or Q_2.

4.3.4 **Longitudinal load distribution factors, $K_{H\beta}$ and $K_{F\beta}$**:

$$K_{H\beta} = 1 + \frac{b\, F_{\beta y}\, C\gamma}{2F_t\, K_A\, K_\gamma\, K_v}$$

Calculated values of $K_{H\beta} > 2$ are to be reduced by improved accuracy and helix correction as necessary:

where

$F_{\beta y} = F_{\beta x} - y_\beta$ and

$F_{\beta x} = 1{,}33 f_{Sh} + f_{ma}$

$f_{ma} = \frac{2}{3}\, F_\beta$ at the design stage, or

$f_{ma} = \frac{2}{3}\, F_\beta$ where helix correction has been applied

$f_{Sh} = f_{Sho}\, \frac{F_t\, K_A\, K_\gamma\, K_v}{b}$ where

f_{Sho} = $23\gamma\ 10^{-3}$ µm mm/N for gears without helix correction or crowning and without end relief, or

= $12\gamma\ 10^{-3}$ µm mm/N for gears without helix correction but with crowning[1]

= $16\gamma\ 10^{-3}$ µm mm/N for gears without helix correction or crowning but with end relief, where

$\gamma = \left(\frac{b}{d_1}\right)$ for single helical and spur gears

$= 3\left(\frac{b}{2d_1}\right)^2$ for double helical gears

The following minimum values are applicable, these also being the values where helix correction has been applied:

f_{Sho} = 10×10^{-3} µm mm/N for helical gears, or

= 5×10^{-3} µm mm/N for spur gears

For through-hardened steels and surface hardened steels running on through-hardened steels:

$y_\beta = \frac{320}{\sigma_{H\,lim}}\, F_{\beta x}$ up to an upper limit value of

$y_\beta = \frac{12800}{\sigma_{H\,lim}}$ m, and

For surface hardened steels, when

$y_\beta = 0{,}15 F_{\beta x}$ up to an upper limit value of

$y_\beta = 6$ m

$F_{F\beta} = K_{H\beta}\, n$

where

$$n = \frac{\left(\frac{b}{h}\right)^2}{1 + \frac{b}{h} + \left(\frac{b}{h}\right)^2}$$

NOTES

1. $\frac{b}{h}$ is to be taken as the smaller of $\frac{b_1}{h_1}$ or $\frac{b_2}{h_2}$

2. For double helical gears $\frac{b}{2}$ is to be substituted for b in the equation for n.

4.3.5 **Transverse load distribution factors, $K_{H\alpha}$ and $K_{F\alpha}$**

$K_{H\alpha} = K_{F\alpha} \geq 1{,}000$

where

$\varepsilon\gamma \leq 2$

$$K_{H\alpha} = \frac{\varepsilon\gamma}{2}\left(0{,}9 + \frac{0{,}4C\gamma\,(f_{pb} - Y_\alpha)\, b}{F_t\, K_A\, K_\gamma\, K_v\, K_{H\beta}}\right)$$

where

$\varepsilon\gamma \leq 2$

$$K_{H\alpha} = 0{,}9 + 0{,}4\sqrt{\frac{2\,(\varepsilon_\gamma - 1)}{\varepsilon_\gamma}}\left(\frac{C_\gamma\,(f_{pb} - y_\alpha)\, b}{F_t\, K_A\, K_\gamma\, K_v\, K_{H\beta}}\right), \text{ but}$$

$K_{H\alpha} \leq \frac{\varepsilon_\gamma}{\varepsilon_a\, Z_\varepsilon^2}$ and

$K_{F\alpha} \leq \frac{\varepsilon_\gamma}{0{,}25\varepsilon_\gamma + 0{,}75}$

When tip relief is applied, f_{pb} is to be half of the maximum specified value:

$y_\alpha = \frac{160}{\sigma_{H\,lim}}\, f_{pb}$ for through-hardened steels, when

$y_\alpha \leq \frac{6400}{\sigma_{H\,lim}}$ µm and

$y_\alpha = 0{,}075 f_{pb}$ for surface hardened steels, when

$y_\alpha \leq 3$ µm

When pinion and wheel are manufactured from different materials:

$$y_\alpha = \frac{y_{\alpha 1} + y_{\alpha 2}}{2}$$

NOTE

Tip relief is to take the form of either tip and root relief on the pinion, or tip relief on pinion and wheel.

4.3.6 **Tooth mesh stiffness, C_γ**:

$$C_\gamma = \frac{0{,}8}{q^1}\cos\beta\,(0{,}75\varepsilon_\alpha + 0{,}25) \quad \text{N/mm µm}$$

where

$$q^1 = 0{,}04723 + \frac{0{,}1551}{z_{n1}} + \frac{0{,}25791}{z_{n2}} - 0{,}00635x_1 - \frac{0{,}11654x_1}{z_{n1}} - 0{,}00193x_2 - \frac{0{,}24188x_2}{z_{n2}} + 0{,}00529x_1^2 + 0{,}00182x_2^2$$

For internals gears $z_{n2} = \infty$

Other calculation methods for C_γ will be specially considered.

4.4 Tooth loading for surface stress

4.4.1 The Hertzian contact stress, σ_H, at the pitch circle is not to exceed the allowable Hertzian contact stress, σ_{HP}:

$$\sigma_H = Z_H\, Z_E\, Z_\varepsilon\, Z_\beta \sqrt{\frac{F_t\,(u+1)}{d_1\, bu}\, K_A\, K_\gamma\, K_v\, K_{H\beta}\, K_{Ha}}$$

and

$$\sigma_{HP} = \frac{\sigma_{H\,lim} Z_R Z_v Z_X}{S_{H\,min}} \text{ for the pinion/wheel combination}$$

where

$$Z_H = \sqrt{\frac{2 \cos \beta_b \cos \alpha_{tw}}{\cos^2 \alpha_t \sin \alpha_{tw}}}$$

$$Z_E = 189{,}8 \text{ for steel}$$

$$Z_\varepsilon = \sqrt{\frac{4 - \varepsilon_\alpha}{3}(1 - \varepsilon_\beta) + \frac{\varepsilon_\beta}{\varepsilon_\alpha}} \quad \text{for } \varepsilon_\beta < 1 \text{ and}$$

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}} \quad \text{for } \varepsilon_\beta \geq 1$$

$$Z_\beta = \sqrt{\cos\beta}$$

$$Z_R = \left(\frac{1}{R_a}\right)^{0,11} \quad \text{but } Z_R \leq 1{,}14$$

Where R_a is the surface roughness value of the tooth flanks. When pinion and wheel tooth flanks differ then the larger value of R_a is to be taken:

$$Z_v = 0{,}88 + 0{,}23 \left(0{,}8 + \frac{32}{v}\right)^{-0,5}$$

For values of Z_x, *see* Table 1.4.2
$\sigma_{H\,lim}$, *see* Table 1.4.3
$S_{H\,min}$, *see* Table 1.4.4.

Table 1.4.2 Values of Z_x

Pinion heat treatment		Z_x
Carburized and induction-hardened	$m_n \leq 10$ $10 < m_n < 30$ $30 \leq m_n$	1,00 $1{,}05 - 0{,}005\, m_n$ 0,9
Nitrided	$m_n < 7{,}5$ $7{,}5 < m_n < 30$ $30 \leq m_n$	1,00 $1{,}08 - 0{,}005\, m_n$ 0,75
Through-hardened	All modules	1,00

Table 1.4.3 Values of endurance limit for Hertzian contact stress, $\sigma_{H\,lim}$

Heat treatment		
Pinion	Wheel	
Through-hardened	Through-hardened	$0{,}46\sigma_{B2} + 255$
Surface-hardened	Through-hardened	$0{,}42\sigma_{B2} + 415$
Carburized, nitrided or induction-hardened	Soft bath nitrided (tufftrided)	1000
Carburized, nitrided or induction-hardened	Induction-hardened	$0{,}88HV_2 + 675$
Carburized or nitrided	Nitrided	1300
Carburized	Carburized	1500

Table 1.4.4 Factors of safety

	$S_{H\,min}$	$S_{F\,min}$
Main propulsion gears	1,40	1,80
Auxiliary gears	1,15	1,40

4.5 Tooth loading for bending stress

4.5.1 The bending stress at the tooth root, σ_F is not to exceed the allowable tooth root bending stress σ_{FP}:

$$\sigma_F = \frac{F_t}{b\, m_n} Y_F Y_S Y_\beta K_A K_\gamma K_v K_{F\beta} K_{F\alpha} \quad \text{N/mm}^2$$

$$\sigma_{FP} = \frac{\sigma_{F\,lim} Y_{ST} Y_{d\,rel\,T} Y_{R\,rel\,T} Y_x}{S_{F\,min} Y_D} \quad \text{N/mm}^2$$

NOTE
If b_1 and b_2 are not equal the load bearing width of the wider face taken is not to exceed that of the smaller plus $2m_n$.

For values of $S_{F\,min}$, *see* Table 1.4.4
$\sigma_{F\,lim}$, *see* Table 1.4.5
Stress correction factor $Y_{ST} = 2$.

Table 1.4.5 Values of endurance limit for bending stress, $\sigma_{F\,lim}$

Heat treatment	$\sigma_{F\,lim}$ N/mm^2
Through-hardened carbon steel	$0{,}09\sigma_B + 150$
Through-hardened alloy steel	$0{,}1\sigma_B + 185$
Soft bath nitrided (Tufftrided)	330
Induction hardened	$0{,}35\, HV + 125$
Gas nitrided	390
Carburized A	450
Carburized B	410
NOTES 1. A is applicable for Cr Ni Mo carburizing steels. 2. B is applicable for other carburizing steels.	

4.5.2 **Tooth form factor, Y_F:**

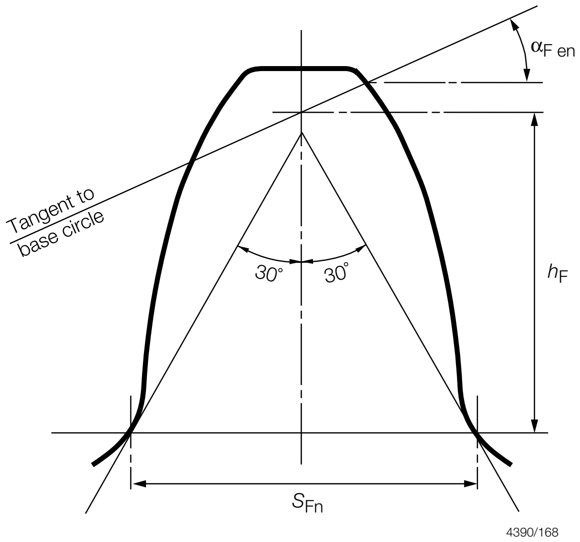
$$Y_F = \frac{6 \dfrac{h_F}{m_n} \cos \alpha_{Fen}}{\left(\dfrac{S_{Fn}}{m_n}\right)^2 \cos \alpha_n}$$

where
h_F, α_{Fen} and S_{Fn} are shown in Fig. 1.4.1.

$$\frac{S_{Fn}}{m_n} = z_n \sin\left(\frac{\pi}{3} - \nu\right) + \sqrt{3}\left(\frac{G}{\cos \nu} - \frac{\rho_{ao}}{m_n}\right)$$

where

$$\nu = \frac{2G}{z_n} \tan \nu - H$$



NOTE
For helical gears the normal section is taken with the virtual number of teeth

Fig. 1.4.1 Normal tooth section

$$G = \frac{\rho_{ao}}{m_n} - \frac{h_{ao}}{m_n} + x$$

$$H = \frac{2}{z_n}\left(\frac{\pi}{2} - \frac{E}{m_n}\right) - \frac{\pi}{3}$$

$$E = \frac{\pi}{4} m_n - h_{ao}\tan\alpha_n + \frac{S_{pr}}{\cos\alpha_n} - (1 - \sin\alpha_n)\frac{\rho_{ao}}{\cos\alpha_n}$$

E, h_{ao}, α_n, S_{pr} and ρ_{ao} are shown in Fig. 1.4.2.

$$\frac{\rho_F}{m_n} = \frac{\rho_{ao}}{m_n} + \frac{2G^2}{\cos\nu\,(z_n\cos^2\nu - 2G)}$$

$$d_{en} = \frac{2z}{|z|}\left\{\left[\sqrt{\left(\frac{d_n}{2}\right)^2 - \left(\frac{d_{bn}}{2}\right)^2} - \frac{\pi d\cos\beta\cos\alpha_n}{|z|}(\varepsilon_{\alpha n} - 1)\right]^2 + \left(\frac{d_{bn}}{2}\right)^2\right\}^{1/2}$$

where

$$d_{an} = d_n + d_a - d$$

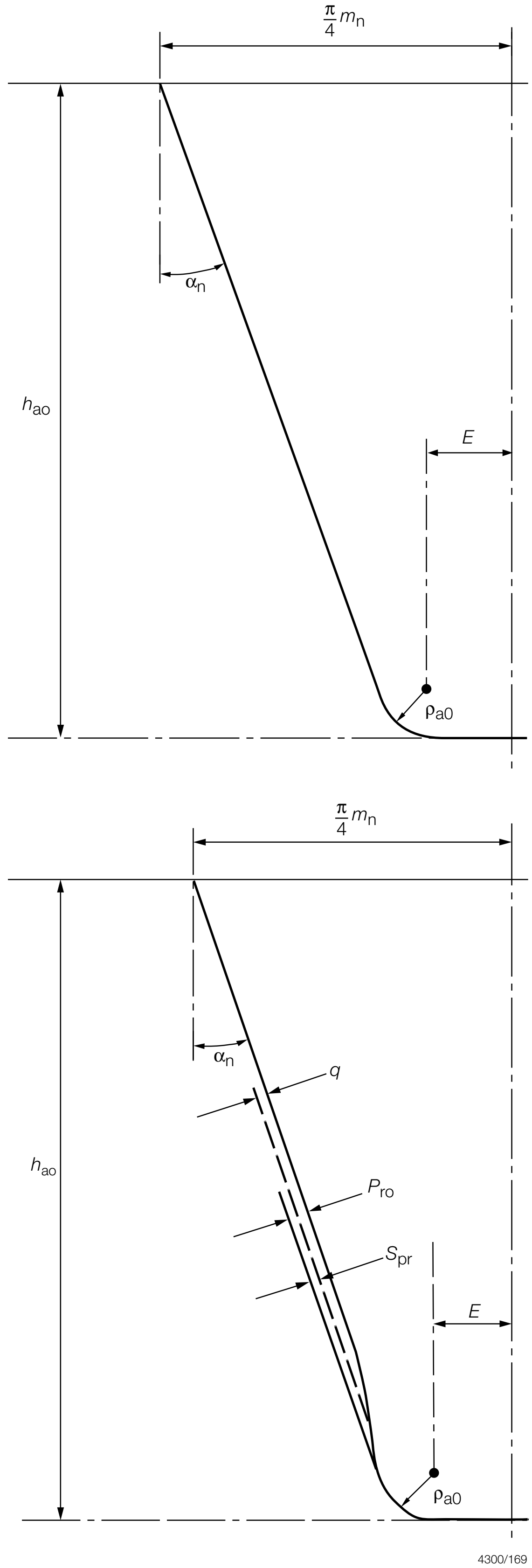
$$d_n = \frac{d}{\cos^2\beta_b}$$

$$d_{bn} = d_n\cos\alpha_n$$

$$\varepsilon_{\alpha n} = \frac{d}{\cos^2\beta_b}$$

$$\gamma_e = \frac{\frac{\zeta\pi}{2} + 2x\tan\alpha_n}{z_n} + \text{inv. }\alpha_n - \text{inv. }\alpha_{en}$$

where



NOTES
1. Dimensions shown in rack profile of tooth
2. $S_{pr} = P_{ro} - q$

Fig. 1.4.2 External tooth forms

$$\alpha_{en} = \arc\cos \frac{d_{bn}}{d_{en}}$$

$$\frac{h_F}{m_n} = \frac{1}{2}\left[(\cos\gamma_e - \sin\gamma_e \tan\alpha_{F\,en})\frac{d_{en}}{m_n} - z_n\cos\left(\frac{\pi}{3} - \nu\right) - \frac{G}{\cos\nu} + \frac{\rho_{ao}}{m_n}\right]$$

where

$\alpha_{F\,en} = \alpha_{en} - \gamma_e$.

4.5.3 For internal tooth forms the form factor is calculated, as an approximation, for a substitute gear rack with the form of the basic rack in the normal section, but having the same tooth depth as the internal gear:

$$\frac{S_{Fn2}}{m_n} = 2\left[\frac{\pi}{4} + \tan\alpha\left(\frac{h_{ao2} - \rho_{ao2}}{m_n}\right) + \left(\frac{\rho_{ao2} - S_{pr}}{m_n}\right) - \frac{\rho_{ao2}}{m_n}\cos\frac{\pi}{6}\right], \text{ and}$$

$$\frac{h_{F2}}{m_n} = \frac{d_{en2} - d_{fn2}}{2m_n} - \left[\frac{\pi}{4} + \left(\frac{h_{ao2}}{m_n} - \frac{d_{en2} - d_{fn2}}{2m_n}\right)\tan\alpha_n\right]\tan\alpha_n - \frac{\rho_{ao2}}{m_n}\left(1 - \sin\frac{\pi}{6}\right)$$

where

$\alpha_{F\,en}$ is taken as being equal to α_n

$$\rho_{F2} = \frac{\rho_{ao2}}{2}$$

d_{en2} is calculated as d_{en} for external gears, and

$d_{fn} = d - d_f - d_n$

4.5.4 **Stress concentration factor, Y_s**

$$Y_s = (1,2 + 0,13L)\, q_s^{\left(\frac{1}{1,21 + 2.3/L}\right)}$$

where

$$L = \frac{S_{Fn}}{h_F}$$

$$q_S = \frac{S_{Fn}}{2\rho_F}$$

when

$q_s < 1$ the value of Y_s is to be specially considered.

The formula for Y_s is applicable to external gears with α_n = 20° but may be used as an approximation for other pressure angles and internal gears.

4.5.5 **Helix angle factor Y_β**

$$Y_\beta = 1 - \left(\varepsilon_\beta \frac{\beta}{120}\right), \text{ if } \varepsilon_\beta > 1 \text{ let } \varepsilon_\beta = 1$$

but

$Y_b \geq 1 - 0,25\varepsilon_\beta \geq 0,75$

4.5.6 **Relative notch sensitivity factor, $Y_{\delta\,rel\,T}$**

$Y_{\delta\,rel\,T}$ = $1 + 0,036\,(q_s - 2,5)\left(1 - \frac{\sigma_y}{1200}\right)$ for through-hardened steels

= $1 + 0,008\,(q_s - 2,5)$ for carburized and induction-hardened steels, and

= $1 + 0,04\,(q_s - 2,5)$ for nitrided steels

4.5.7 **Relative surface finish factor, $Y_{R\,rel\,T}$**

$Y_{R\,rel\,T}$ = $1,674 - 0,529\,(6R_a + 1)^{0,1}$ for through-hardened, carburized and induction hardened steels, and

= $4,299 - 3,259\,(6R_a + 1)^{0,005}$ for nitrided steels

4.5.8 **Size factor, Y_x**

Y_x = 1,00, when $m_n \leq 5$

= $1,03 - 0,006m_n$ for through-hardened steels

= 0,85, when $m_n \geq 30$

= $1,05 - 0,01\,m_n$ for surface-hardened steels

= 0,80, when $m_n \geq 25$

4.5.9 **Design factor, Y_D**

Y_D = 0,83 for gears treated with a controlled shot peening process

= 1,5 for idler gears

= 1,25 for shrunk on gears, or

$$= 1 + \frac{0,2d_s^2\,d\,P_r\,b}{F_t\,\sigma_{F\,lim}\,(d_f^2 - d_s^2)}, \text{ otherwise}$$

= 1,00, or any combination of the above – e.g. Y_D = (0,83 x 1,5) for an idler gear treated with a controlled shot peening process.

4.6 Factors of safety

4.6.1 Factors of safety are shown in Table 1.4.4.

4.7 Design of enclosed gear shafting

4.7.1 The following symbols apply:

P in kW and R in rpm, *see* 1.2.1.

L = span between shaft bearing centres, in mm

α_n = normal pressure angle at the gear reference diameter, in degrees

β = helix angle at the gear reference diameter, in degrees

d_w = pitch circle diameter of the gear teeth, in mm

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2

NOTE

Numerical value used for σ_u is not to exceed 800 N/mm^2 for gear and thrust shafts and 1100 N/mm^2 for quill shafts.

4.7.2 This sub-Section is applicable to the main and ancillary transmission shafting, enclosed within the gearcase.

4.7.3 The diameter of the enclosed gear shafting adjacent to the pinion or wheel is to be not less than the greater of d_b or d_t, where:

$$d_b = 365 \left(\frac{P\,L}{R\,d_w\,S_b} \right)^{1/3} \left(1 + \left(\frac{\tan \alpha_n}{\cos\beta} + \frac{\tan\beta\,d_w}{L} \right)^2 \right)^{1/6}$$

$$d_t = 365 \left(\frac{P}{R\,S_s} \right)^{1/3}$$

where

$S_b = 45 + 0{,}24\,(\sigma_u - 400)$ and

$S_s = 42 + 0{,}09\,(\sigma_u - 400)$

4.7.4 For the purposes of the above it is assumed that the pinion or wheel is mounted symmetrically spaced between bearings.

4.7.5 Outside a length equal to the required diameter at the pinion or wheel, the diameter may be reduced, if applicable, to that required for d_t.

4.7.6 For bevel gear shafts, where a bearing is located adjacent to the gear section, the diameter of the shaft is to be not less than d_t. Where a bearing is not located adjacent to the gear the diameter of the shaft will be specially considered.

4.7.7 The diameter of quill shaft (not axially constrained and subject only to external torsional loading) is to be not less than given by the following formula:

$$\text{Diameter of quill shaft} = 101 \sqrt[3]{\frac{P400}{R\,\sigma_u}} \quad \text{mm}$$

4.7.8 Where a shaft, located within the gearcase, is subject to the main propulsion thrust, the diameter at the collars of the shaft transmitting torque, or in way of the axial bearing where a roller bearing is used as a thrust bearing, is to be not less than $1{,}1d_t$. For thrust bearings located outside the gearcase, *see* Chapter 2.

4.8 Gear wheels

4.8.1 In general, arrangements are to be made so that the interior structure of the wheel may be examined. Alternative proposals will be specially considered.

4.9 External shafting and components

4.9.1 For shafting external to the gearbox and other components ancillaries, *see* Pt 11, Ch 2.

4.10 Clutch actuation

4.10.1 Where a clutch is fitted in the transmission, normal engagement shall not cause excessive stresses in the transmission or the driven machinery. Inadvertent operation of any clutch is not to produce dangerously high stresses in the transmission or driven machinery.

4.11 Gearcases

4.11.1 Gearcases and their supports are to be designed sufficiently stiff such that misalignment at the mesh due to movements of the external foundations and the thermal effects under all conditions of service do not disturb the overall tooth contact.

4.11.2 Inspection openings are to be provided at the peripheries of gearcases to enable the teeth of pinions and wheels to be readily examined. Where the construction of gearcases is such that sections of the structure cannot be readily be moved for inspection purposes, access openings of adequate size are also to be provided at the ends of the gearcases to permit examination of the structure of the wheels. Their attachment to the shafts is to be capable of being examined by removal of bearing caps or by equivalent means.

4.11.3 For gearcases fabricated by fusion welding the carbon content of the steels should generally not exceed 0,23 per cent. Steels with higher carbon content may be approved subject to satisfactory results from weld procedure tests.

4.11.4 Gearcases are to be stress relieved upon completion of all welding.

4.11.5 Gearcases manufactured from material other than steel will be considered upon full details being submitted.

4.12 Alignment

4.12.1 Reduction gears with sleeve bearings, for main and auxiliary purposes are to be provided with means for checking the internal alignment of the various elements in the gearcases.

4.12.2 In the case of separately mounted reduction gearing for main propulsion, means are to be provided by the gear manufacturer to enable the Surveyors to verify that no distortion of the gearcase has taken place, when chocked and secured to its seating on board the craft.

■ *Section 5*
Piping systems for gearing

5.1 General

5.1.1 Piping systems for gearing are to comply with the general design requirements given in Part 15.

5.1.2 The specific requirements for lubricating/hydraulic oil systems and standby arrangements are given in Part 15.

5.1.3 Lubricating oil lines are to be screened, or otherwise suitably protected, to avoid oil spray or oil leakages onto hot surfaces, into machinery air intakes or other sources of ignition. The number of joints in such piping systems should be kept to a minimum. Flexible pipes are to be of an approved type.

5.2 Pumps

5.2.1 Where lubricating oil for the reduction gearing is circulated under pressure, pump standby arrangements are to be provided in accordance with Part 15.

5.3 Filters

5.3.1 Where the lubricating oil for the reduction gearing is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the gear set or reducing the supply of filtered oil to the gearing.

■ *Section 6* Control and monitoring

6.1 General

6.1.1 Control engineering systems are to be in accordance with Part 16.

6.1.2 All main and auxiliary gear units, intended for essential services, are to be provided with means of indicating the lubricating oil supply pressure. Audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. These alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

6.2 Unattended machinery

6.2.1 Where the machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, gear units are to be provided with the alarms and safety arrangements required by 6.2.2 and Table 1.6.1. The sensors and circuits utilised for the second stage alarm and automatic shut down in Table 1.6.1 are to be independent of those required for the first stage alarm.

Table 1.6.1 Alarms and safeguards

Item	Alarm	Note
Lubricating oil sump level	Low	
Lubricating oil inlet pressure*	1st Stage Low	
	2nd Stage Low	Automatic shutdown of engine
Lubricating oil inlet temperature*	High	
Thrust bearing temperature*	High	
NOTE For transmitted powers of 1500 kW or less, only the items marked * are required.		

6.2.2 Where the gear unit is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pump falls below a predetermined value.

■ *Section 7* Requirements for craft which are not required to comply with the HSC Code

7.1 Details to be submitted

7.1.1 Failure mode effect analysis is not required for craft which do not require to comply with the HSC Code.

7.1.2 Mass elastic schematic showing gear unit torsional data is only required for gears with an input power greater than 500 kW, *see* 2.2.2 and Part 13.

7.2 Design of gearing

7.2.1 Where they are not intended for passenger carrying duties, the gearing factors of safety for yachts, service craft less than 24 m and ACVs are to satisfy Table 1.7.1.

Table 1.7.1 Factors of safety

	SH min	SF min
Main propulsion gears for yachts, etc., single screw	1,25	1,50
Main propulsion gears for yachts, etc., multiple screw	1,20	1,45

7.3 Piping systems

7.3.1 For service craft less than 24 m and for yachts the requirements of 5.2.1 and 5.3.1 do not apply. These craft are to have gearing provided with an efficient lubricating oil pump, a cooler where necessary, and a filter arrangement which can be cleaned.

7.4 Control and monitoring

7.4.1 For service craft less than 24 m the alarms required by 6.2.1 are not required.

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 This Chapter gives the requirements for the dimensions of transmission shafts, couplings, coupling bolts, keys, keyways, sternbushes and other associated components of main propulsion shafting.

1.1.3 The diameters may require to be modified as a result of alignment considerations and vibration characteristics (*see* Part 13), or the inclusion of stress raisers, other than those contained in this Chapter.

1.1.4 For shafting enclosed within an gearbox, *see* Ch 1,4.7.

1.1.5 For diesel engine crankshaft and turbine rotor shafting, *see* Part 10.

1.2 Power ratings

1.2.1 In this Chapter, the dimensions of main propulsion component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, and general requirements defined in Pt 9, Ch 1,1.

1.2.2 For auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute which will be used in service are to be stated.

1.3 Clutches

1.3.1 Clutches for single engine propulsion plants are to be provided with a suitable means for emergency operation in the event of loss of operating fluid systems. Their suitability for short term high power operation is to be demonstrated.

1.4 Safety

1.4.1 Means are to be provided such that in the event of a failure to a shaft or coupling the occupants of the craft are not endangered, either directly or by damaging the craft or its systems. Where necessary, guards may be fitted to achieve compliance with these requirements.

■ *Section 2* Particulars to be submitted

2.1 Plans

2.1.1 At least three copies of the following plans are to be submitted:
- Shafting arrangement.
- Thrust shaft.
- Intermediate shafting.
- Tube shaft, where applicable.
- Screwshaft.
- Screwshaft oil gland.
- Screwshaft protection.
- Sternbush and arrangement in housing.
- Couplings.
- Coupling bolts.
- Flexible coupling.
- Cardan shafts.

2.1.2 The shafting arrangement plan is to indicate the relative position of the main engine(s), flywheel, flexible coupling(s), gearing, thrust block, line shafting and bearing(s), sterntube, 'A' bracket and propulsion device, as applicable.

2.2 Calculations and specifications

2.2.1 The following calculations and specifications are to be submitted:
- Calculations, or relevant documentation indicating the suitability of all components for short term high power operation, where applicable.
- Where undertaken as an alternative to the requirements of this Chapter, fatigue endurance calculations of all components according to Part 9.
- Vibration analysis and alignment analysis as required by Part 13.
- The material specifications, including the minimum specified tensile strength of each shaft and coupling component are to be stated. Where corrosion resistant material not included in Table 2.4.1 is used for unprotected screwshafts the corrosion fatigue strength in sea-water is to be stated together with the chemical composition and mechanical properties.
- Where it is proposed to use composite (non-metallic) shafts, details of materials, resin, lay-up procedure and documentary evidence of fatigue endurance strength.

Section 3 **Materials**

3.1 Materials for shafts

3.1.1 Components are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. For main propulsion shafting, not exposed to sea water, in alloy steels, the specified minimum tensile strength is not to exceed 800 N/mm^2 and for other forgings is not to exceed 1100 N/mm^2.

3.1.3 Unprotected screwshafts and tubeshafts exposed to sea-water are in general to be manufactured, from corrosion resistant ferrous or non-ferrous material, such as those indicated in Table 2.4.1.

3.1.4 In the selection of materials for shafts, keys, locking nuts etc., consideration is to be given to their compatibility with the proposed propeller material.

3.1.5 Where shafts are manufactured from composite material the process is to be approved.

Section 4 **Design and construction**

4.1 Fatigue strength analysis

4.1.1 As an alternative to the following requirements, a fatigue strength analysis of components can be submitted indicating a factor of safety of 1,5 at the design loads, based on a suitable fatigue failure criteria. The effects of stress concentrations, material properties and operating environment are to be taken into account.

4.2 Intermediate shafts

4.2.1 The diameter, *d*, of the intermediate shaft is to be not less than:

$$d = F\,k\,\sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)} \text{ mm}$$

where

k = 1,0 for shafts with integral coupling flanges complying with 4.8 or shrink fit couplings
= 1,10 for shafts with keyways, where the fillet radii in the transverse section of the bottom of the keyway are not less than 0,0125*d*
= 1,10 for shafts with transverse or radial holes where the diameter of the hole does not exceed 0,3*d*
= 1,20 for shafts with longitudinal slots having a length of not more than 1,4*d* and a width of not more than 0,2*d* where *d*, is determined with *k* = 1,0

F = 95 for turbine installations, electric propulsion installations and diesel engine installations with slip type couplings
= 100 for other diesel engine installations

P and *R* are as defined in Part 9

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2

4.2.2 Beyond a length of 0,2*d* from the end of a keyway, transverse hole or radial hole and 0,3*d* from the end of a longitudinal slot, the diameter of the shaft may be gradually reduced to that determined with *k* = 1,0.

4.2.3 For shafts with design features other than stated as above, the value of *k* will be specially considered.

4.2.4 The Rule diameter of the intermediate shaft for diesel engines, turbines and electric propelling motors may be reduced by 3,5 per cent for craft classed G1 (Service Group 1), *see* Pt 1, Ch 2,3.5.

4.3 Thrust shafts

4.3.1 The diameter at the collars of the thrust shaft transmitting torque or in way of the axial bearing where a roller bearing is used as a thrust bearing is to be not less than that required for the intermediate shaft in accordance with 4.2 with a *k* value of 1,10. Beyond a length equal to the thrust shaft diameter from the collars, the diameter may be tapered down to that required for the intermediate shaft with a *k* value of 1,0. For the purpose of the foregoing calculations, σ_u is to be taken as the minimum tensile strength of the thrust shaft material, in N/mm^2.

4.4 Screwshafts and tube shafts

4.4.1 Screwshafts and tube shafts, (i.e the shaft which passes through the sterntube, but does not carry the propeller), made from carbon manganese steel are to be protected by a continuous bronze liner, where exposed to sea water. Alternatively, the liner may be omitted provided the shaft is arranged to run in an oil lubricated bush with an approved oil sealing gland at the after end. Lengths of shafting between sterntubes and brackets, which are readily visible when the craft is slipped, may be protected by coatings of an approved type.

4.4.2 Means for the protection of screwshafts and tube-shafts are not required when the shafts are made of corrosion resistant material.

4.4.3 The diameter, d_p of the protected forged steel screwshaft immediately forward of the forward face of the propeller boss or, if applicable, the forward face of the screw-shaft flange, is to be not less than:

$$d_p = 100k\,\sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)} \text{ mm}$$

where

k = 1,22 for a shaft carrying a keyless propeller, or where the propeller is attached to an integral flange, and where the shaft is fitted with a continuous liner, a coating of an approved type, or is oil lubricated and provided with an approved type of oil sealing gland
= 1,26 for a shaft carrying a keyed propeller and where the shaft is fitted with a continuous liner, a coating of an approved type, or is oil lubricated and provided with an approved type of oil sealing gland

P and R are as defined in Part 9

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2 but is not to be taken as greater than 600 N/mm^2.

4.4.4 The diameter, d_p of the screwshaft determined in accordance with 4.4.3 is to extend over a length not less than that to the forward edge of the bearing immediately forward of the propeller or $2{,}5d_p$ whichever is the greater.

4.4.5 The diameter of the portion of the screwshaft and tube shaft forward of the length required by 4.4.4 to the forward end of the stern tube seal is to be determined in accordance with 4.4.3 with a k value of 1,15. The change of diameter from that determined with k = 1,22 or 1,26 to that determined with k = 1,15 should be gradual.

4.4.6 Screwshafts which run in sterntubes and tube shafts may have the diameter forward of the forward stern tube seal gradually reduced to the diameter of the intermediate shaft. Abrupt changes in shaft section at the screwshaft/tube shaft to intermediate shaft couplings are to be avoided.

4.4.7 The diameter of unprotected screwshafts and tube shafts of materials having properties as shown in Table 2.4.1 is to be not less than:

$$d_{up} = 128A \sqrt[3]{\frac{P}{R}}$$

where 'A' is taken from Table 2.4.1 and
P and R are as defined in Part 9.

Table 2.4.1 Provisional 'A' Value for use in unprotected screwshaft formula

Material	'A' Value
Stainless steel type 316 (austenitic)	0,71
Stainless steel type 431 (martensitic)	0,69
Manganese bronze	0,8
Aluminium bronze	0,65
Nickel copper alloy – monel 400	0,65
Nickel copper alloy – monel K 500	0,55
Duplex steels	0,49

4.4.8 The diameter of the unprotected screwshaft forward of the stern seal need not be greater than the diameter as required by 4.4.6.

4.5 Hollow shafts

4.5.1 Where the thrust, intermediate, tube shafts and screwshafts have central holes having a diameter greater than 0,4 times the outside diameter, the equivalent diameter, d_e, of a solid shaft is not to be less than the Rule size, d, (of a solid shaft), where d_e is given by:

$$d_e = d_o \sqrt[3]{1 - \left(\frac{d_i}{d_o}\right)^4}$$

where

d_o = proposed outside diameter, in mm

d_i = diameter of central hole, in mm.

4.5.2 Where the diameter of the central hole does not exceed 0,4 times the outside diameter, the diameter is to be calculated in accordance with the appropriate requirements for a solid shaft.

4.6 Cardan shafts

4.6.1 Cardan shafts, used in installations having more than one propulsion shaftline, are to be of an approved design, suitable for the designed operating conditions including short term high power operation. Consideration will be given to accepting the use of approved cardan shafts in single propulsion unit applications if a complete spare interchangeable end joint is provided on board.

4.6.2 Cardan shaft ends are to be contained within substantial tubular guards that also permit ready access for inspection and maintenance.

4.7 Coupling bolts

4.7.1 Close tolerance fitted bolts transmitting shear are to have a diameter, d_b, at the flange joining faces of the couplings not less than:

$$d_b = \sqrt{\frac{240}{nD} \frac{10^6}{\sigma_u} \frac{P}{R}} \text{ mm}$$

where

n = number of bolts in the coupling

D = pitch circle diameter of bolts, in mm

σ_u = specified minimum tensile strength of bolts, in N/mm^2

P and R are as defined in Part 9.

4.7.2 At the joining faces of couplings, other than within the crankshaft and at the thrust shaft/crankshaft coupling, the Rule diameter of the coupling bolts may be reduced by 5,2 per cent for craft classed exclusively for smooth water service.

4.7.3 Where dowels or expansion bolts are fitted to transmit torque in shear they are to comply with the requirements of 4.7.1. The expansion bolts are to be installed, and the bolt holes in the flanges are to be correctly aligned in accordance with manufacturer's instructions.

4.7.4 The minimum diameter of tap bolts or of bolts in clearance holes at the joining faces of coupling flanges, pretensioned to 70 per cent of the bolt material yield strength value, is not to be less than:

$$d_R = 1{,}348 \sqrt{\left(\frac{120\ 10^6\ F\ P\ (1 + C)}{R\ D} + Q \right) \frac{1}{n\ \sigma_y}}$$

where d_R is taken as the lesser of:

(a) Mean of effective (pitch) and minor diameters of the threads.

(b) Bolt shank diameter away from threads. (Not for waisted bolts which will be specially considered.)

P and *R* are defined in Part 9.

F = 2,5 where the flange connection is not accessible from within the craft
= 2,0 where the flange connection is accessible from within the craft

C = ratio of vibratory/mean torque values at the rotational speed being considered

D = pitch circle diameter of bolt holes, in mm

Q = external load on bolt in N (+ve tensile load tending to separate flange, –ve)

n = number of tap or clearance bolts

σ_y = bolt material yield stress in N/mm^2.

4.7.5 Consideration will be given to those arrangements where the bolts are pretensioned to loads other than 70 per cent of the material yield strength.

4.7.6 Where clamp bolts are fitted they are to comply with the requirements of 4.7.4 and are to be installed, and the bolt holes in the flanges correctly aligned, in accordance with manufacturer's instructions.

4.8 Flange connections of couplings

4.8.1 The minimum thicknesses of the coupling flanges are to be equal to the diameters of the coupling bolts at the face of the couplings as required by 4.7.1, and for this purpose the minimum tensile strength of the bolts is to be taken as equivalent to that of the shafts. For intermediate, thrust shafts, and the inboard end of of the screwshaft, the thickness of the coupling flange is in no case to be less than 0,20 of the diameter of the intermediate shaft as required by 4.2.1.

4.8.2 The fillet radius at the base of the coupling flange, integral with the shaft, is to be not less than 0,08 of the diameter of the shaft at the coupling. The fillets are to have a smooth finish and are not to be recessed in way of nut and bolt heads.

4.8.3 Where the propeller is attached by means of a flange, the thickness of the flange is to be not less than 0,25 of the actual diameter of the adjacent part of the screwshaft. The fillet radius at the base of the coupling flange is to be not less than 0,125 of the diameter of the shaft at the coupling.

4.8.4 All couplings which transmit torque are to be of approved dimensions.

4.8.5 Where couplings are separate from the shafts, provision is to be made to resist the astern pull.

4.8.6 Where a coupling is shrunk on to the parallel portion of a shaft or is mounted on a slight taper, e.g. by means of the oil pressure injection method, the assembly is to meet the requirements of 4.11.

4.9 Tooth couplings

4.9.1 The contact stress, S_c, at the flanks of mating teeth of a gear coupling is not to exceed that given in Table 2.4.2, where

$$S_c = \frac{24{,}10^6\ P}{R\ d_p\ bhz} \quad \text{N/mm}^2$$

where

P and *R* are defined in Part 9.

d_p = pitch circle diameter of coupling teeth, in mm

b = tooth facewidth, in mm

h = tooth height, in mm

z = number of teeth (per coupling half).

Table 2.4.2 Allowable S_c values

Tooth material surface treatment	Allowable S_c Value N/mm^2
Surface hardened teeth	19
Through hardened teeth	11

4.9.2 Where experience has shown that under similar operating and alignment conditions, a higher tooth loading can be accommodated full details are to be submitted for consideration.

4.10 Flexible couplings

4.10.1 Details of flexible couplings are to be submitted together with the manufacturer's rating capacity, for the designed operating conditions including short term high power operation. Verification of coupling characteristics will be required.

4.10.2 In determining the allowable mean, maximum and vibratory torque ratings consideration of the mechanical properties of the selected elastic element type in compression, shear and fatigue loading together with heat absorption/ generation is to be given.

4.10.3 In determining the allowable torque ratings of the steel spring couplings, consideration of the material mechanical properties to withstand fatigue loading and overheating is to be given.

4.11 Interference fit assemblies

4.11.1 The interference fit assembly is to have a capacity to transmit a torque of $S.T_{max}$ without slippage.

NOTE

For guidance purposes only $T_{max} = T_{mean}\ (1 + C)$

where

C is to be taken from Table 2.4.3

S = 2,0 for assemblies accessible from within the vessel
= 2,5 for assemblies not accessible from within the vessel.

4.11.2 The effect of any axial load acting on the assembly is to be considered.

Table 2.4.3 '*C*' values for guidance purposes

Coupling location	*C*
High Speed Shafting — I.C engine driven	0,3
High Speed Shafting — Electric Motor or Turbine driven	0,1
Low Speed Shafting — main or PTO stage gearing	0,1

4.11.3 The resulting equivalent von Mises stress in the assembly is not to be greater than the yield strength of the component material.

4.11.4 Reference marks are to be provided on the adjacent surfaces of parts secured by shrinkage alone.

4.12 Keys and keyways for propeller connections

4.12.1 Round ended or sled-runner ended keys are to be used, and the keyways in the propeller boss and cone of the screwshaft are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the screwshaft at the top of the cone. The sharp edges at the top of the keyways are to be removed.

4.12.2 Two screwed pins are to be provided for securing the key in the keyway, and the forward pin is to be placed at least one-third of the length of the key from the end. The depth of the tapped holes for the screwed pins is not to exceed the pin diameter, and the edges of the holes are to be slightly bevelled. The omission of pins for keys for small diameter shafts will be specially considered.

4.12.3 The distance between the top of the cone and the forward end of the keyway is to be not less than 0,2 of the diameter of the screwshaft at the top of the cone.

4.12.4 The effective sectional area of the key in shear, is to be not less than:

$$\frac{155d^3}{\sigma_u\, d_1}\ \text{mm}^2$$

where

d = diameter, in mm, required for the intermediate shaft determined in accordance with 4.2, based on material having a specified minimum tensile strength of 400 N/mm^2 and k = 1

d_1 = diameter of shaft at mid-length of the key, in mm

σ_u = specified minimum tensile strength (UTS) of the key material, N/mm^2.

4.12.5 The effective area in crushing of key, shaft or boss is to be not less than:

$$\frac{24d^3}{\sigma_y\, d_1}\ \text{mm}^2$$

where

σ_y = yield strength of key, shaft or boss material as appropriate, N/mm^2.

4.13 Keys and keyways for inboard shaft connections

4.13.1 Round ended keys are to be used and the keyways are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the shaft at the coupling. The sharp edges at the top of the keyways are to be removed.

4.13.2 The effective area of the key in shear, A, is to be not less than:

$$A = \frac{126d^3}{\sigma_u\, d_1}\ \text{mm}^2$$

where

d = diameter, in mm, required for the intermediate shaft determined in accordance with 4.2, based on material having a specified minimum tensile strength of 400 N/mm^2 and k = 1

d_1 = diameter of shaft at mid-length of the key, in mm

σ_u = specified minimum tensile strength (UTS) of the key material, N/mm^2

Alternatively, consideration will be given to keys conforming to the design requirements of a recognised National Standard.

4.14 Corrosion resistant liners on shafts

4.14.1 Liners may be bronze, gunmetal, stainless steel or other approved alloy.

4.14.2 The thickness, t, of liners fitted on screwshafts or on tube shafts, in way of the bushes, is to be not less, when new, than given by the following formula:

$$t = \frac{D + 230}{32}\ \text{mm}$$

where

t = thickness of the liner, in mm

D = diameter of the screwshaft or tube shaft under the liner, in mm.

4.14.3 The thickness of a continuous liner between the bushes is to be not less than 0,75t.

4.14.4 Continuous liners are to be fabricated or cast in one piece.

4.14.5 Where liners consist of two or more lengths, these are to be butt welded together. In general, the lead content of the gunmetal of each length forming a butt welded liner is not to exceed 0,5 per cent. The composition of the electrodes or filler rods is to be substantially lead-free.

4.14.6 The circumferential butt welds are to be of multi-run, full penetration type. Provision is to be made for contraction of the weld by arranging for a suitable length of the liner containing the weld, if possible about three times the shaft diameter, to be free of the shaft. To prevent damage to the surface of the shaft during welding, a strip of heat resisting material covered by a copper strip should be inserted between the shaft and the liner in way of the joint. Other methods for welding this joint may be accepted if approved. The welding is to be carried out by an approved method and to the Surveyor's satisfaction.

4.14.7 Each continuous liner or length of liner is to be tested by hydraulic pressure to 2,0 bar after rough machining.

4.14.8 Liners are to be carefully shrunk onto the shafts by hydraulic pressure. Pins are not to be used to secure the liners.

4.14.9 Effective means are to be provided for preventing water from reaching the shaft at the part between the after end of the liner and the propeller boss.

4.15 Intermediate bearings

4.15.1 Long unsupported lengths of shafting are to be avoided by the fitting of steady bearings at suitable positions, *see* Part 13.

4.16 Sternbushes and sterntube arrangement

4.16.1 Where the sterntube or sternbushes are to be installed using a resin, of an approved type, the following requirements are to be met:

(a) Pouring and venting holes are to be provided at opposite ends with the vent hole at the highest point.
(b) The minimum radial gap occupied by the resin is to be not less than 6 mm at any one point with a nominal resin thickness of 12 mm.
(c) In the case of oil lubricated sterntube bearings, the arrangement of the oil grooves is to be such as to promote a positive circulation of oil in the bearing.
(d) Provision is to be made for the remote measurement of the temperature at the aft end of the aft bearing, with indication and alarms at the control stations.

4.16.2 The length of the bearing in the sternbush next to and supporting the propeller is to be as follows:

(a) For water lubricated bearings which are lined with rubber composition or staves of approved plastics material, the length is to be not less than four times the diameter required for the screwshaft under the liner.
(b) For water lubricated bearings lined with two or more circumferentially spaced sectors, of an approved plastics material, without axial grooves in the lower half, the length of the bearing is to be such that the nominal bearing pressure will not exceed 0,55 N/mm^2. The length of the bearing is to be not less than twice its diameter.
(c) For bearings which are white-metal lined, oil lubricated and provided with an approved type of oil sealing gland, the length of the bearing is to be approximately twice the diameter required for the screwshaft and is to be such that the nominal bearing pressure will not exceed 0,8 N/mm^2. The length of the bearing is to be not less than 1,5 times its diameter.
(d) For bearings of cast iron and bronze which are oil lubricated and fitted with an approved oil sealing gland, the length of the bearing is, in general, to be not less than four times the diameter required for the screwshaft.
(e) Oil lubricated non-metallic bearings are to be manufactured from an approved material. The length of the bearing is to be such that the maximum approved bearing pressure is not exceeded for any limiting length to diameter ratio.

4.16.3 Sternbushes are to be adequately secured in housings.

4.16.4 Forced water lubrication is to be provided for all bearings lined with rubber or plastics. The supply of water may come from a circulating pump or other pressure source. Flow indicators are to be provided for the water service to plastics and rubber bearings. The water grooves in the bearings are to be of ample section and of a shape which will be little affected by weardown, particularly for bearings of the plastics type.

4.16.5 The shut-off valve or cock controlling the supply of water is to be fitted directly to the after peak bulkhead, or to the sterntube where the water supply enters the sterntube forward of the bulkhead.

4.16.6 Oil sealing glands must be capable of accommodating the effects of differential expansion between hull and line of shafting for all sea temperatures in the proposed area of operation. This requirement applies particularly to those glands which span the gap and maintain oiltightness between the sterntube and the propeller boss.

4.16.7 Where a tank supplying lubricating oil to the sternbush is fitted, it is to be located above the load waterline and is to be provided with a low level alarm device in the machinery space, *see also* 5.1.1.

4.16.8 Where sternbush bearings are oil lubricated, provision is to be made for cooling the oil by maintaining water in the after peak tank above the level of the sterntube or by other approved means. Means for ascertaining the temperature of the oil in the sterntube are also to be provided.

4.16.9 Where an ***IWS** (In-water Survey) notation is to be assigned, means are to be provided for ascertaining the clearance in the sternbush with the vessel afloat.

4.17 Vibration and alignment

4.17.1 For the requirements for torsional, axial and lateral vibration, and for alignment of the shafting, *see* Part 13.

■ *Section 5* Control and monitoring

5.1 Unattended machinery

5.1.1 Where sterntube lubrication oil systems are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms indicated in Table 2.5.1.

Table 2.5.1 Alarms

Item	Alarm
Sterntube lubricating oil tank level	Low
Sterntube bearing temperature (oil lubricated)	High

■ *Section 6* Requirements for craft which are not required to comply with the HSC Code

6.1 General

6.1.1 Service craft of less than 24 m do not have to comply with 1.3.1 in respect of emergency operation of clutches on single screw installations.

6.2 Details to be submitted

6.2.1 The corrosion fatigue strength of corrosion resistant shaft material need not be submitted if the material is as shown in Table 2.4.1, *see also* 2.2.

6.3 Materials

6.3.1 The proposals to use extruded non-ferrous or composite materials will receive special consideration.

6.3.2 For the survey and testing of shaft material, *see* the Rules for Materials.

6.4 Sternbushes and sterntube arrangement

6.4.1 For service craft less than 24 m, the requirements of 4.16.1 do not apply. Sterntube bearings of approved plastics materials are to be installed so as to ensure a supply of water for lubrication in accordance with the bearing manufacturer's recommendations.

6.4.2 The aftermost propeller shaft bearing in the sterntube is to be secured to prevent rotational and axial movement.

6.4.3 For service craft less than 24 m, the requirements of 4.16.8 do not apply.

6.4.4 The lubrication of propulsion shafting bearings on SES craft less than 24 m will be considered.

6.5 Alarms

6.5.1 The requirements of 5.1.1 do not apply to service craft less than 24 m.

RULES AND REGULATIONS FOR THE CLASSIFICATION OF SPECIAL SERVICE CRAFT

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1.1 Application

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1.2 Power ratings

1.2.1 In this Chapter where the dimensions of main propulsion components are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in Part 9.

1.3 Highly skewed propellers

1.3.1 The maximum skew angle of a propeller blade is defined as the angle, in projected view of the blade, between a line drawn through the blade tip and the shaft centreline and a second line through the shaft centreline which acts as a tangent to the locus of the mid-points of the helical blade sections, *see* Fig. 1.1.1.

1.4 Supercavitating propellers

1.4.1 A supercavitating propeller is defined as one in which the sheet cavity is designed to cover the entire blade width over at least the outer 50 per cent of the blade span.

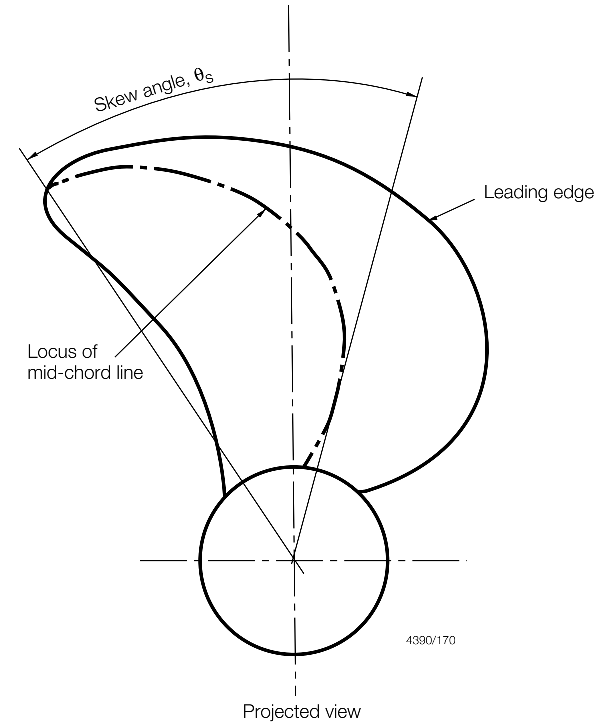

Fig. 1.1.1 Definition of skew angle

■ *Section 2* Plans and particulars

2.1 Particulars to be submitted

2.1.1 At least three copies of the following plans and information are to be submitted.

2.2 Plans

2.2.1 A plan of the propeller, together with the following particulars is to be submitted:

(a) Maximum blade thickness of the expanded cylindrical section considered, in mm, excluding any allowance for fillet, *T*, in mm.
(b) Maximum shaft power, *P*, in kW, *see* Part 9.
(c) Estimated craft speed at design loaded draught in the free running condition at maximum shaft power and corresponding revolutions per minute (*see* (b) and (d)).
(d) Revolutions per minute of the propeller at maximum power, *R*.
(e) Propeller diameter, *D*, in metres.
(f) Pitch at 25 per cent radius (for solid propellers only), $P_{0,25}$, in metres.
(g) Pitch at 35 per cent radius (for controllable pitch propellers only), $P_{0,35}$, in metres.
(h) Pitch at 60 per cent radius, $P_{0,6}$, in metres.
(j) Pitch at 70 per cent radius, $P_{0,7}$, in metres.

(k) Length of blade section of the expanded cylindrical section at 25 per cent radius (for solid propellers only), $L_{0,25}$, in mm.
(l) Length of blade section of the expanded cylindrical section at 35 per cent radius (for controllable pitch propellers only), $L_{0,35}$, in mm.
(m) Length of blade section of the expanding cylindrical section at 60 per cent radius, $L_{0,6}$, in mm.
(n) Rake at blade tip measured at shaft axis (backward rake positive, forward rake negative), A, in mm.
(o) Number of blades, N.
(p) Developed area ratio, B.
(q) Material: type and specified minimum tensile strength.
(r) Skew angle, θ_s, in degrees, *see* Fig. 1.1.1.
(s) Connection of propeller to shaft- details of fit, push up and securing.
(t) Keyed connection details.
(u) Details of control/hydraulic system and pressures for CP Propellers actuating mechanisms.
(v) Inertia of propeller assembly, kgm^2.
(w) Total mass of propeller assembly, kg.

2.2.2 For propellers having a skew angle equal or greater than 50° in addition to the particulars detailed in 2.2.1 details are to be submitted of:
(a) Full blade section details at each radial station defined for manufacture.
(b) A detailed blade stress computation supported by the following hydrodynamic data for the ahead mean wake condition and when absorbing full power:
    (i) Radial distribution of lift and drag coefficients, section inflow velocities and hydrodynamic pitch angles.
    (ii) Section pressure distributions calculated by either an advised viscid or viscous procedure.

2.3 Calculations and information

2.3.1 In cases where the craft has been the subject of model wake field tests a copy of the results is to be submitted.

2.3.2 The following information is to be submitted as applicable:

- For controllable pitch propellers plans (in diagrammatic form) of the hydraulic systems together with pipe material and working pressures.
- Details of control engineering aspects in accordance with Part 16.
- Calculations, or relevant documentation indicating the suitability of all components for short term high power operation.
- Where undertaken, fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads.
- For cases where the propeller material is not specified in Table 1.3.1, details of the chemical composition, mechanical properties and density are to be provided, together with results of fatigue tests in sea water in order to assign a value for U.

Section 3 **Materials**

3.1 Castings for propellers

3.1.1 Castings for propellers and propeller blades are to comply with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). The chemical composition and mechanical properties of steel castings are given in Ch 4,5 of the Rules for Materials and those of the copper alloys are given in Ch 9,1 of the Rules for Materials.

3.1.2 The specified minimum tensile strength of the castings is to be not less than stated in Table 1.3.1.

Table 1.3.1 Materials for propellers

Material	Specified minimum tensile strength N/mm^2	G Density g/cm^3	U Allowable stress N/mm^2
Carbon steels	400	7,9	20,6
Low alloy steels	440	7,9	20,6
13% chromium stainless steels	540	7,7	41
Chromium – nickel austenitic stainless steel	450	7,9	41
Duplex stainless steels	590	7,8	41
Grade Cu 1 Manganese bronze (high tensile brass)	440	8,3	39
Grade Cu 2 Ni-Manganese bronze (high tensile brass)	440	8,3	39
Grade Cu 3 Ni-Aluminium bronze	590	7,6	56
Grade Cu 4 Mn-Aluminium bronze	630	7,5	46

3.1.3 Where propellers of carbon and low alloy steels shown in Table 1.3.1 are provided with an approved method of cathodic protection, special consideration will be given to the value of U.

Section 4 Propeller design

4.1 Minimum blade thickness

4.1.1 For propellers having a skew angle of less than 25° as defined in 1.3.1, the minimum blade thickness, *T*, of the propeller blades at 25 per cent radius for solid propellers, 35 per cent radius for controllable pitch propellers, neglecting any increase due to fillets, and at 60 per cent radius, is to be not less than:

$$T = \frac{KCA}{EFULN} + 100\sqrt{\frac{3150MP}{EFRULN}} \text{ mm}$$

where

$L = L_{0,25}$, $L_{0,35}$, or $L_{0,6}$, as appropriate

$K = \dfrac{GBD^3R^2}{675}$

G = density, in g/cm^3, *see* Table 1.3.1

U = allowable stress, in N/mm^2, *see* 4.1.2, 4.1.3, 4.1.4 and Table 1.3.1.

$E = \dfrac{\text{actual face modulus}}{0{,}09T^2L}$

For aerofoil sections with and without trailing edge washback, *E* may be taken as 1,0 and 1,25 respectively.

For solid propellers at 25 per cent radius

$C = 1{,}0$

$$F = \frac{P_{0,25}}{D} + 0{,}8$$

$$M = 1{,}0 + \frac{3{,}75D}{P_{0,7}} + 2{,}8\frac{P_{0,25}}{D}$$

For controllable pitch propellers at 35 per cent radius

$C = 1{,}4$

$$F = \frac{P_{0,35}}{D} + 1{,}6$$

$$M = 1{,}35 + \frac{5D}{P_{0,7}} + 2{,}6\frac{P_{0,35}}{D}$$

For all propellers at 60 per cent radius

$C = 1{,}6$

$$F = \frac{P_{0,6}}{D} + 4{,}5$$

$$M = 1{,}35 + \frac{5D}{P_{0,7}} + 1{,}35\frac{P_{0,6}}{D}$$

4.1.2 The fillet radius between the root of a blade and the boss of a propeller is to be not less than the Rule thickness of the blade or equivalent at this location. Composite radiused fillets or elliptical fillets which provide a greater effective radius to the blade are acceptable and are to be preferred. Where fillet radii of the required size cannot be provided, the value of *U* is to be multiplied by

$$\left(\frac{r}{T}\right)^{0,2}$$

where

r = proposed fillet radius at the root, in mm

T = Rule thickness of the blade at the root, in mm.

Where a propeller has bolted-on blades, consideration is also to be given to the distribution of stress in the palms of the blades. In particular, the fillets of recessed bolt holes and the lands between bolt holes are not to induce stresses which exceed those permitted at the outer end of the fillet radius between the blade and the palm. Counterbored bolt holes in blade flanges are to be provided with adequate fillet radii at the bottom of the counter bore.

4.1.3 The value *U* may be increased by 10 per cent for twin screw and outboard propellers of triple screw craft.

4.1.4 For propellers having skew angles of 25° or greater, but less than 50°, the mid chord thickness, $T_{sk0,6}$, at the 60 per cent radius is to be not less than:

$$T_{sk0,6} = 0{,}54T_{0,6}\sqrt{(1 + 0{,}1\theta_s)} \text{ mm}$$

The mid chord thickness, $T_{sk\ root}$, at 25 or 35 per cent radius, neglecting any increase due to fillets, is to be not less than:

$$T_{sk\ root} = 0{,}75T_{root}\sqrt[4]{(1 + 0{,}1\theta_s)} \text{ mm}$$

where

θ_s = proposed skew angle as defined in 1.3.1

$T_{0,6}$ = thickness at 60 per cent radius, calculated by 4.1.1

$T_{sk\ root}$ = thickness at 25 per cent radius or 35 per cent radius, calculated by 4.1.1

The thickness at the remaining radii are to be joined by a fair curve and the sections are to be of suitable aerofoil section.

4.1.5 Results of detailed calculations where carried out, are to be submitted.

4.1.6 Where the design of a propeller has been based on analysis of reliable wake survey data in conjunction with a detailed fatigue analysis and is deemed to permit scantlings less than required by 5.1.1, a detailed stress analysis for the blades is to be submitted for consideration.

4.2 Interference fit of keyless propellers

4.2.1 The symbols used in 4.2.2 are defined as follows:

d_1 = diameter of the screwshaft cone at the mid-length of the boss or sleeve, in mm

d_3 = outside diameter of the boss at its mid-length, in mm

d_i = bore diameter of screwshaft, in mm

$$k_3 = \frac{d_3}{d_1}$$

$$l = \frac{d_i}{d_1}$$

$$p_1 = \frac{2M}{A_1\,\theta_1\,V_1}\left(-1 + \sqrt{1 + V_1\left(\frac{F_1^2}{M^2} + 1\right)}\right)$$

A_1 = contact area fitting at screwshaft, in mm^2

$$B_3 = \frac{1}{E_3}\left(\frac{k_3^2 + 1}{k_3^2 - 1} + \nu_3\right) + \frac{1}{E_1}\left(\frac{1 + l^2}{1 - l^2} - \nu 1\right)$$

C = 0 for turbine installations or electric propulsion

$= \dfrac{\text{vibratory torque at the service speed}}{\text{mean torque at the service speed}}$ for oil engine installations

E_1 = modulus of elasticity of screwshaft material, in N/mm^2

E_3 = modulus of elasticity of propeller material, in N/mm^2

$$F_1 = \frac{2000Q}{d_1}(1 + C)$$

M = propeller thrust, in N

Q = mean torque corresponding to P and R as defined in Part 9, in Nm

T_1 = temperature at time of fitting propeller on shaft, in °C

$$V_1 = 0{,}51\left(\frac{\mu_1}{\theta_1}\right)^2 - 1$$

α_1 = coefficient of linear expansion of screwshaft material, in mm/mm/°C

α_3 = coefficient of linear expansion of propeller material, in mm/mm/°C

θ_1 = taper of the screwshaft cone, but is not to exceed $\dfrac{1}{15}$ on the diameter, i.e. $\theta_1 \le \dfrac{1}{15}$

μ_1 = coefficient of friction for fitting of boss assembly on shaft

= 0,13 for oil injection method of fitting

ν_1 = Poisson's ratio for screwshaft material

ν_3 = Poisson's ratio for propeller material.

4.2.2 Where it is proposed to fit a keyless propeller by the oil shrink method, the pull-up, δ on the screwshaft is to be not less than:

$$\delta = \frac{d_1}{\theta_1}\left(p_1 B_3 + (\alpha_3 - \alpha_1)(35 - T_1)\right) \text{ mm}$$

The yield stress or 0,2 per cent proof stress, σ_0, of the propeller material is to be not less than:

$$\sigma_0 = \frac{1{,}4}{B_3}\left(\frac{\theta_1 \delta_p}{d_1} + T_1(\alpha_3 - \alpha_1)\right)\frac{\sqrt{3k_3^4 + 1}}{k_3^2 - 1} \text{ N/mm}^2$$

where

δ_p = proposed pull-up at the fitting temperature.

The start point load, W, to determine the actual pull-up is to be not less than:

$$W = A_1\left(0{,}002 + \frac{\theta_1}{20}\right)\left(p_1 + \frac{18}{B_3}(\alpha_3 - \alpha_1)\right) \text{ N.}$$

4.3 Keyed propellers pushed up by an hydraulic nut

4.3.1 Calculations are to be undertaken to show that the proof stress of the boss material is not exceeded in way of the keyway root fillet radius. In order to reduce the likelihood of frettage a grip stress of not less than 20 N/mm^2 between boss and shaft is to be achieved.

4.4 Propeller boss

4.4.1 The forward edge of the bore of the propeller boss is to be rounded to a 6 mm radius. In the case of keyed propellers, the length of the forward fitting surface is to be about one diameter.

4.4.2 Drilling holes through propeller bosses is to be avoided, except where it is essential to the design.

4.5 Fixed and steering nozzles

4.5.1 The requirements for scantlings for fixed and steering nozzles are given in Pt 3, Ch 3,4.

■ *Section 5* Piping systems

5.1 General

5.1.1 The piping system for a controllable pitch propeller is to comply with the general design requirements given in Part 15.

5.1.2 The specific requirements for lubricating hydraulic oil systems and standby arrangements are given in Part 15.

5.1.3 The hydraulic power operating systems are to be provided with arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system.

■ *Section 6* Control and monitoring

6.1 General

6.1.1 Control and monitoring is to comply with the requirements of Pt 16, Ch 1.

6.2 Automatic and remote controls

6.2.1 Where controllable pitch propellers are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by 6.2.2, 6.2.3 and Table 1.6.1.

6.2.2 For controllable pitch propellers for main propulsion, a standby or alternative power source of actuating medium for controlling the pitch of the propeller blades is to be provided. Automatic start of the standby pump supplying hydraulic power for pitch control is to be provided.

Table 1.6.1 Alarms

Item	Alarm	Note
Hydraulic system pressure	Low	–
Hydraulic oil supply tank level	Low	–
Hydraulic oil temperature	High	Where an oil cooler is fitted
Power supply to the control system between the remote control station and hydraulic actuator	Failure	Failure of any power supply to a control system is to operate an audible and visual alarm
Propulsion motor	Overload	*See* Part 16

6.2.3 For controllable pitch propellers, a shaft speed indicator and a pitch indicator which shows the degree of pitch as a measure of the propeller blade or actuator movement are to be provided at each station from which it is possible to control shaft speed or propeller pitch.

■ *Section 7* Requirements for craft which are not required to comply with the HSC Code

7.1 Propellers not exceeding one metre in diameter

7.1.1 The materials and the scantlings need not comply with Sections 1 to 3 inclusive or 4.1 to 4.3 inclusive.

7.1.2 Propellers for service craft less than 24 m and main engine power output not exceeding 500 kW are to be manufactured from materials in accordance with the Rules for Materials at a works recognised for the quality of its casting and machining, and be free from defects.

7.1.3 Certificates of construction are not required.

7.1.4 Specific requirements for the piping systems are given in Part 15.

7.1.5 The alarm and monitoring arrangements, and for controllable pitch propellers, the safety arrangements and standby power sources, will be specially considered, *see also* Part 16.

7.2 Alternative materials and design

7.2.1 Propellers made from materials not listed in the Rules for Materials or of unusual form or design will be specially considered.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 This Chapter gives requirements for fixed or steerable water jet propulsion systems where the rated power exceeds 500 kW, and which are integral with the craft's hull structure and form the main means of propulsion. The arrangements of water jet units for other purposes will be considered in relation to their intended duty.

1.1.3 A water jet propulsion unit is defined as a machine which takes in water, by means of a suitable inlet and ducting system, and accelerates the mass of water using an impeller and nozzle to form a jet propulsion system.

1.2 Redundancy

1.2.1 In general a minimum of two water jet units are to be provided where these form the sole means of propulsion.

1.2.2 The failure of one water jet unit or its control system is not to render any other water jet unit inoperative.

1.2.3 Where a single water jet installation is proposed, it will be subject to special consideration, taking into account the proposed restricted area notation. A formal risk assessment will be required in these cases.

■ *Section 2* Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the following plans and information as detailed in 2.2 and 2.3 are to be submitted.

2.2 Plans

2.2.1 General arrangement plans showing details of the following:
(a) Shafting assembly indicating bearing positions.
(b) Steering assembly.
(c) Reversing assembly.
(d) Longitudinal section of the complete water jet unit.

2.2.2 Detailed dimension plans indicating scantlings and materials of construction of the following:
(a) Arrangement of the system, including intended method of attachment to the hull and building in, geometry of tunnel, shell openings, method of stiffening, reinforcement, etc.
(b) All torque transmitting components, including impeller, and also stator, if fitted.
(c) Steering components, together with a description and line diagram of the control circuit. This includes steerable exit water jet nozzles where fitted.
(d) Components of retractable buckets where these are used for providing astern thrust.
(e) The bearing or bearings absorbing the thrust and supporting the impeller, together with the method of lubrication.
(f) Shaft sealing arrangements.
(g) Details of any shafting support or guide vanes used in the water jet system.

2.2.3 Schematic plans of the lubricating and hydraulic systems, together with pipe material, relief valves and working pressures.

2.3 Calculations and information

2.3.1 Details of the power/speed range of operation indicating the maximum continuous torque rating together with flow rate and thrust.

2.3.2 Strength calculations, using the maximum continuous torque rating and the most 'onerous' operating condition, including short term high power operation, as a design case including the effects of mean and fluctuating loads, residual stresses, and stress raisers, for:
(a) Impeller and, if fitted, the stator and any bolting arrangements.
(b) Shaft supports and guide vanes if fitted.
In the absence of precise information, the fluctuating stress may be assumed to be 15 per cent of the maximum stress. As an alternative to fatigue strength calculation results of an approved measurement programme may be submitted. In all cases, a factor of safety of at least 1,5 is to be demonstrated for the maximum continuous rating condition.

(c) Detailed weld specification where an impeller has welded blades. Welds are to be of full penetration type or of equivalent strength.
(d) Steering components, including lugs of steerable nozzles, where fitted.
(e) Retractable buckets and associated mechanism, which are used to provide astern thrust. A calculation of the hydrodynamic transient loads is to be made for each design and is to include the full ahead to full astern condition. The calculation procedure used is to be supported, where possible, with appropriate full scale or model test data or satisfactory service experience to validate the design method.

2.3.3 Details of the Designer's loadings and positions of application in the hull are to be submitted, and should include maximum applied thrust, moments and tunnel pressures. The tunnel strength and supporting structure are to be examined by direct calculation procedures and submitted for consideration.

2.3.4 Calculations, or relevant documentation indicating the suitability of all components for short term high power operation, where applicable.

2.3.5 Where it is proposed to use composite (non-metallic) shafts, details of materials, resin, lay-up procedure and documentary evidence of fatigue endurance strength.

2.3.6 Torsional vibration calculations of the complete dynamic system in accordance with Part 13, together with a torsional schematic of the water jet unit.

2.3.7 Shaft whirling calculations where required by Part 13.

2.3.8 Details of control engineering aspects are to be in accordance with Part 16.

■ *Section 3* Materials

3.1 General

3.1.1 The materials used in the construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 Machinery components are to be of steel or other approved non-ferrous metals suitable for the intended environment.

3.2 Fibre reinforced plastic

3.2.1 Fibre Reinforced Plastic materials (FRP) may be used for certain components, provided that they are of adequate strength and comply with the requirements of Part 8.

■ *Section 4* Design and construction

4.1 Shaftline

4.1.1 The diameter of the shafting is to comply with Pt 11, Ch 2. For calculation purposes the shaft carrying the impeller is to be taken as equivalent to a screwshaft.

4.1.2 Where it is proposed to use carbon or carbon manganese steel shafts which may be in contact with sea-water, these are to be protected. Full details of the means of protection are to be submitted.

4.1.3 Where lengths of shafts are joined using couplings of the shrunk element type, full particulars of the method of achieving the grip force are to be forwarded for consideration. A factor of safety against slippage of 2,0, based upon mean plus vibratory torque, is to be achieved for couplings located inboard, and likewise 2,5 for couplings which are located outboard.

4.1.4 For the interference fit of keyless impellers the requirements of Chapter 1 are to be applied.

4.2 Shaft support system and guide vanes

4.2.1 In cases where the shaft requires support from the tunnel walls ahead of the impeller, or, alternatively, where guide vanes are required to assist the flow around a bend in the ducting system, the supports or guide vanes are to be aligned to the flow and have suitably rounded leading and trailing edges or be of an aerofoil section.

4.2.2 Fatigue strength calculations of supports or guide vanes are to be submitted and are to include the effects of mean and fluctuating loads, residual stresses, and stress raisers. In general, the fillet radius should not be less than the maximum thickness at that location. Smaller radii may be considered for which the results of an approved measurement programme are to be submitted. In all cases, a factor of safety of at least 1,5 is to be demonstrated for the designed operating conditions.

4.2.3 A facility for the inspection of the supports or guide vanes is to be provided which will allow either direct visual or boroscope inspection of these components.

4.3 Impeller

4.3.1 In general, the fillet radius should not be less than the maximum thickness at that location. Composite radiused fillets or elliptical fillets which provide an improved stress concentration factor are acceptable and are to be preferred.

4.3.2 Where an impeller has bolted on blades, consider-ation is also to be given to the distribution of stress in the palms of the blade and in the hub and bolting arrangements.

4.3.3 The blades are to be provided with hydrodynamically faired leading and trailing edges which may be either of simple radius or of a more complex aerofoil edge form. The tip clearance, whilst being kept to a minimum for hydrodynamic purposes must be sufficient to allow for any transient vibrational behaviour, axial shaft movement or differential thermal expansion.

4.3.4 A calculation of the blade natural frequency for the impeller blades is to be undertaken. As such the natural frequency should be shown to lie outside any expected excitation frequencies within a speed range of 30 per cent below to 10 per cent above the maximum impeller speed. Deviations from these limits will be considered.

4.3.5 A facility for the in service inspection of the impeller and stator (if fitted) blades is to be provided which will allow for either a direct visual or boroscope inspection of the complete blade surfaces.

4.4 Stator

4.4.1 The stator blades, where fitted, are to be designed to be capable of withstanding the combined hydro-dynamic and mechanical loads (including any loads transmitted via shaft bearings) developed by the unit and reacted through the blades when the impeller is absorbing full power and the vessel is either free running or undergoing a crash stop manoeuvre, whichever imposes the greater loading on the blades.

4.4.2 In general, the fillet radius should not be less than the maximum thickness at that location. Composite radiused fillets or elliptical fillets which provide improved stress concentration factors are acceptable and are to be preferred.

4.4.3 If the stator ring is a composite assembly then consideration is also to be given to the distribution of stress in the various adjacent members.

4.4.4 A calculation of the relative blade passing frequency between the rotor and stator blades is to be carried out and it is to be demonstrated that this does not coincide with the natural frequency of the stator blades over a speed range of 30 per cent below to 10 per cent above maximum impeller speed. Similarly this condition is to be demonstrated for the manoeuvring speeds.

4.4.5 The stator blades are to be provided with hydro-dynamically faired leading edges which may have either a simple radius or a more complex aerofoil edge form.

4.4.6 Where the stator blading assembly forms part of the nozzle, the requirements of 4.6 must be considered in association with those for the stator assembly.

4.5 Tunnel and securing arrangements

4.5.1 The tunnel is to be adequately supported, framed and fully integrated into the hull structure.

4.5.2 The tunnel and supporting structure scantlings are to be not less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

4.5.3 Consideration should be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of this guard must strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

4.5.4 The inlet profile of the tunnel is to be designed so as to provide a smooth uptake of the water over the range of vessel operating trims and avoid significant separating of the flow into the rotating machinery.

4.5.5 Design consideration is to take account of pressures which could develop as a result of a duct blockage, and to the axial location of rotating parts.

4.6 Nozzle and reversing bucket

4.6.1 Nozzles can be either of a fixed or steerable form. The design of the nozzle must fully take into account the change in pressure distribution along its inner surface together with the other mechanical loads (e.g. stator assembly loads) and transient loads caused by the flow directing attachments and bucket loads which may be reacted through the body of the nozzle. In this analysis the changes to the pressure distribution caused by transient manoeuvres are to be considered.

4.6.2 Consideration is to be given to all transient loads the bucket is likely to experience from manoeuvring and the sea conditions.

4.6.3 The bucket is to be given reasonable mechanical protection from other impact damage such as collision with harbour walls, other vessels, buoys, etc.

4.7 Steering system

4.7.1 In general the steering systems are to comply with the requirements of Part 14.

4.7.2 In addition to the requirements of Pt 14, Ch 1, the steering mechanism is to be capable of turning the nozzle unit at not less than 1,5 rev/min.

Section 5
Piping systems

5.1 General

5.1.1 The piping systems for a water jet unit are to comply with the general requirements of Pt 15, Ch 1.

5.1.2 The specific requirements for lubricating hydraulic oil systems and standby arrangements are given in Pt 15, Ch 3. Requirements for steering hydraulic systems are given in Pt 14, Ch 1.

5.2 Hydraulic power systems

5.2.1 The hydraulic power operating systems for each water jet unit are to be provided with the following:
(a) arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system,
(b) a fixed storage tank having sufficient capacity to recharge at least one water jet power actuating system including the reservoir.

Section 6
Control and monitoring

6.1 General

6.1.1 Except where indicated in this Section the control engineering systems are to be in accordance with Pt 16, Ch 1.

6.1.2 Steering control is to be provided for the water jet from machinery control stations.

6.1.3 For water jets used as the only means of propulsion, a standby or alternative power source of actuating medium for controlling the angular position and/or the reversing angle is to be provided. Automatic start of the standby pump supplying hydraulic power for steering and reversing is to be provided.

6.1.4 Means are to be provided at each station to stop each water jet.

6.2 Monitoring and alarms

6.2.1 Alarms and monitoring requirements are indicated in 6.2.2 to 6.2.4 and Table 2.6.1.

6.2.2 An indication of the angular position of the nozzle is to be provided at each station from which it is possible to control the direction of thrust.

6.2.3 An indication of both the required and actual reversing bucket position is to be provided at each station from which it is possible to control the reversal of thrust.

Table 2.6.1 Alarms

Item	Alarm	Note
Hydraulic system pressure	Low	–
Hydraulic oil supply tank level	Low	–
Hydraulic oil temperature	High	Where an oil cooler is fitted
Hydraulic system flow	Low	–
Lubricating oil pressure	Low	–
Control system	Fault	–
Control system power supply	Failure	–

6.2.4 All alarms associated with water jet unit faults are to be indicated individually at the control stations and in accordance with the alarm system specified by Pt 16, Ch 1.

Section 7
Electrical systems

7.1 Distribution arrangements

7.1.1 Water jet auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as is practicable and without the use of common feeders, transformers, convertors, protective devices or control circuits.

Section 8
Requirements for craft which are not required to comply with the HSC Code

8.1 General requirements

8.1.1 Designs of waterjets for all craft having an input power over 110 kW but not greater than 500 kW will be specially considered.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 This Chapter gives requirements for fixed or steerable thruster units (azimuth thrusters) which are used for propulsion and steering, and also applies to transverse propulsion (tunnel) thrusters which are an aid to manoeuvring.

1.1.3 In this Chapter where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in Part 9.

1.2 Redundancy

1.2.1 A minimum of two azimuth thruster units are to be provided where these form the sole means of propulsion. Where a single azimuth thruster installation is proposed, it will be subject to consideration, taking into account the proposed restricted area notation.

1.2.2 The failure of one azimuth thruster unit or its control system is not to render any other thruster inoperative.

1.3 Inclination of craft

1.3.1 Thruster units are to operate satisfactorily under the conditions as shown in Part 9.

■ *Section 2* Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the following plans are to be submitted.

2.1.2 **Fixed/Azimuth propulsion thrusters**
(a) A general arrangement sectional assembly plan showing all the connections of the torque transmitting components from the prime mover to the propeller, together with the azimuthing mechanism and, if a nozzle is provided, the nozzle ring structure and nozzle support struts.
(b) Detailed and dimensional plans of the individual torque transmitting components.
(c) Schematic plans of lubricating and hydraulic systems, together with pipe material, relief valves and working pressures.

2.1.3 **Tunnel thrusters.**
Structural assembly plan including connections to tunnel.

2.2 Calculations and specifications

2.2.1 At least three copies of the following information are to be submitted.

2.2.2 **Fixed/Azimuth propulsion thrusters**
(a) Thruster prime mover type and operational power/speed envelope.
(b) Rating and type of motor for the azimuthing mechanism (e.g. type – hydraulic or electric).
(c) Gearing calculations for the azimuthing mechanism which is to be designed to a recognised National Standard.
(d) Bearing specifications.
(e) Details of control engineering aspects in accordance with Pt 16, Ch 1.
(f) Calculations indicating suitability of components for short term high power operation, where applicable. *See* Part 9.
(g) Where carried out in accordance with Part 9, a fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads, based on a suitable fatigue failure criteria.

2.2.3 **Tunnel thrusters**. Specification for materials of gears, shafts, couplings and propeller, stock and struts.

■ *Section 3* Materials

3.1 Azimuth thrusters

3.1.1 The materials used in the construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

Section 4
Design and construction

4.1 General

4.1.1 The arrangement of all types of thrusters is to be such that the craft can be manoeuvred in accordance with the design specifications.

4.1.2 The requirements associated with the structural and watertight integrity and the installation arrangement are to be in accordance with Pt 3, Ch 3.

4.1.3 In addition to the requirements of this Section reference is to be made to:
(a) Main transmission gearing (Pt 11, Ch 1).
(b) Main transmission shafting (Pt 11, Ch 2).
(c) Propeller (Chapter 1).
(d) Torsional vibration (Pt 13, Ch 1).
(e) Lateral vibration for shafting systems which include cardan shafts (Pt 13, Ch 3).

4.2 Azimuth thrusters

4.2.1 The following requirements are to be complied with:
(a) The azimuthing mechanism is to be capable of a maximum rotational speed of not less than 1,5 rev/min.
(b) Gearing for the azimuthing mechanism is to be designed to a recognised National Standard.
The design is to consider both static ($<10^3$ cycles) and dynamic loading conditions.
(c) Under dynamic operating conditions, the gear is to be considered for
  (i) design maximum dynamic duty steering torque,
  (ii) variable loading, where applicable. A spectrum (duty) factor may be used. The load spectrum value is to be derived using load measurements of similar units, where possible.
(d) Under a static duty ($<10^3$ load cycles) steering torque, which should be not less than M_T, as defined in 4.3.1.
(e) The following minimum factor of safety values are to be achieved:
Surface Stress S_{Hmin} = 1,0.
Bending Stress S_{Fmin} = 1,5.
(f) For hydraulic pressure retaining parts and load bearing components, *see also* Part 14.

4.3 Azimuth thrusters with a nozzle

4.3.1 Where the propeller is contained within a nozzle, the equivalent rudder stock diameter in way of tiller, used in Table 1.4.1 in Pt 14, Ch 1 is to be determined as follows:

$$d_{SU} = 26{,}03 \sqrt[3]{(V + 3)^2 A_N X_{PF}} \quad \text{mm}$$

where

V = maximum service speed, in knots, which the craft is designed to maintain under thruster operation

A_N = projected nozzle area, in m^2, and is equal to the length of the nozzle multiplied by the mean external vertical height of the nozzle

X_{PF} = horizontal distance from the centreline of the steering tube to the centre of pressure, in metres. The position of the centre of pressure is determined from Table 3.2.6 in Pt 3, Ch 3.

The corresponding maximum turning moment, M_T, is to be determined as follows:

$$M_T = 11{,}1 \times d_{SU}^3 \quad \text{Nmm}$$

4.3.2 In addition to the requirements of Part 3 the scantlings of the nozzle stock or steering tube are to be such that the section modulus Z against transverse bending at any section x–x is not less than:

$$Z = 1{,}73 \sqrt{(V + 3)^4 A_N^2 X_{PF}^2 + \frac{a^2}{4} T_M^2 \, 10^4} \quad \text{cm}^3$$

where

a = dimension, in metres, as shown in Fig. 3.4.1

T_M = maximum thrust of the thruster unit, in tonnes.

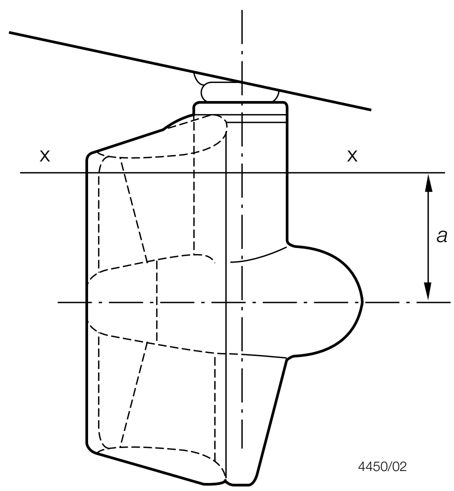

Fig. 3.4.1 Azimuth thruster

4.3.3 The scantlings of nozzle connections or struts will be specially considered. In the case of certain high powered craft, direct calculation may be required.

4.3.4 Where the propeller is not contained in a nozzle, the scantlings in way of the tiller will be subject to special consideration.

Section 5
Piping systems

5.1 General

5.1.1 The piping system for azimuth thrusters is to comply with the general design requirements given in Pt 15, Ch 1.

5.1.2 The specific requirements for lubricating/hydraulic oil systems and standby arrangements are given in Pt 15, Ch 3.

5.2 Azimuth thruster

5.2.1 The hydraulic power operating systems for each azimuth thruster are to be provided with the following:

(a) arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system,

(b) a fixed storage tank having sufficient capacity to recharge at least one azimuth power actuating system including the reservoir. The piping from the storage tank is to be permanent and arranged in such a manner as to allow recharging from within the thruster space.

5.2.2 Where the lubricating oil for the azimuth thrusters is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the thruster or reducing the supply of filtered oil.

■ *Section 6* Control and monitoring

6.1 General

6.1.1 Except where indicated in this Section the control engineering systems are to be in accordance with Pt 16, Ch 1.

6.1.2 Azimuthing control for azimuth thruster(s) and propeller pitch control for azimuth and/or tunnel thruster(s) are to be provided from the navigating bridge, the main machinery control station and locally.

6.1.3 Means are to be provided at the remote control station(s) to stop each azimuth or tunnel thruster unit.

6.2 Monitoring and alarms

6.2.1 Alarms and monitoring requirements are indicated in 6.2.2, 6.2.3 and Table 3.6.1.

6.2.2 An indication of the angular position of the azimuth thruster(s) and the propeller pitch position for azimuth and/or tunnel thruster(s) are to be provided at each station from which it is possible to control the direction of thrust or the pitch.

6.2.3 All alarms associated with thruster unit faults are to be indicated individually on the navigating bridge and in accordance with the alarm system specified by Part 16.

Table 3.6.1 Alarms

Item	Alarm	Note
Thruster, azimuth or tunnel	—	Indicators, *see* 6.2.2
Azimuthing motor	Power failure, single phase	Also running indication on bridge and at machinery control station
Propeller pitch motor	Power failure	Also running indication on bridge and at machinery control station
Propulsion motor	Overload, power failure	Also running indication on bridge and at machinery control station
Control system	Failure	
Hydraulic oil supply tank level	Low	
Hydraulic oil system pressure	Low	
Hydraulic oil system temperature	High	Where oil cooler is fitted
Hydraulic oil filters differential pressure	High	Where oil filters are fitted
Lubricating oil supply pressure	Low	If separate forced lubrication

■ *Section 7* Electrical systems

7.1 General

7.1.1 The electrical installation is to be designed, constructed and installed in accordance with the requirements of Part 16.

7.2 Emergency power for steering systems and drives

7.2.1 For high speed craft, in the event of total power failure, either:

(a) emergency power for steering systems/drives is to be restored automatically within five seconds. To achieve this an interim fast acting system may be required to come into operation until such time as the auxiliary/emergency power source comes on line. (Note: starting arrangements are to comply with the requirements relating to starting arrangements of emergency generators), or

(b) means are to be provided to bring the craft to a safe condition.

7.3 Circuits

7.3.1 Azimuth thruster auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as is practicable and without the use of common feeders, transformers, converters, protective devices or control circuits.

■ *Section 8*
Requirements for craft which are not required to comply with the HSC Code

8.1 Design and installation

8.1.1 Tunnel thrusters on service craft less than 24 m and yachts which are not essential for steering and manoeuvring do not have to comply with the design requirements of this Chapter.

8.1.2 The installation of such thrusters is to be such as to maintain the structural and watertight integrity of the craft.

8.2 Control and monitoring

8.2.1 Alarms and monitoring requirements of Table 3.6.1 are not required for service craft of less than 24 m.

RULES AND REGULATIONS FOR THE CLASSIFICATION OF SPECIAL SERVICE CRAFT

SHAFT VIBRATION AND ALIGNMENT

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PART 13

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Chapter Contents Part 13

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Chapter Contents Part 13

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of Parts 9, 10, 11 and 12.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to the following systems:

(a) Main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

(b) Machinery driven at constant speed by oil engines, developing 110 kW and over, for essential auxiliary services including generator sets which are the source of power for main electric propulsion motors.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, *P*, in kW, and revolutions per minute, *R*, are referred to, the values to be used are those defined in Part 9.

1.3 Basic requirements

1.3.1 System designs are to take account of the potential effects of engine and component malfunction and variability in characteristic values.

1.3.2 Where torques, stresses or amplitudes are found to exceed the limits for continuous operation, restrictions in speed and/or power will be imposed.

■ *Section 2* Details to be submitted

2.1 Particulars to be submitted

2.1.1 Torsional vibration calculations, including an analysis of the vibratory torques and stresses for the full dynamic system.

2.1.2 Particulars of the division of power and utilisation, throughout the speed range, for turbines, multi-engine or other combined power installations, and those with power take-off systems. For multi-engined installations, special considerations associated with the possible variations in the mode of operation and phasing of engines.

2.1.3 Details of operating conditions encountered in service for prolonged periods, e.g. idling speed, combinator characteristics for installations equipped with controllable pitch propellers.

2.1.4 Details, obtained from the manufacturers, of the principal characteristics of machinery components such as dampers and couplings, confirming their capability to withstand the effects of vibratory loading including, where appropriate, heat dissipation. Evidence that the data which is used to represent the characteristics of components, which has been quoted from other sources, is supported by a programme of physical measurement and control.

2.1.5 Where installations include electric motors, generators or non-integral pumps, drawings showing the principal dimensions of the shaft, together with the manufacturer's estimates of mass moment of inertia for the rotating parts.

2.1.6 Details of vibration or performance monitoring proposals where required.

2.2 Scope of calculations

2.2.1 Calculations are to be carried out, by recognized techniques, for the full dynamic system formed by the oil engines, turbines, motors, generators, flexible couplings, gearing, shafting and propeller, where applicable, including all branches.

2.2.2 Calculations are to give due consideration to the potential deviation in values used to represent component characteristics due to manufacturing/service variability.

2.2.3 The calculations carried out on oil engine systems are to be based on the Enginebuilders' harmonic torque data. (On request, Lloyd's Register (hereinafter referred to as 'LR') can provide a table of generalised harmonic torque components for use where appropriate.) The calculations are to take account of the effects of engine malfunction commonly experienced in service, such as a cylinder not firing. Calculations are also to take account of a degree of imbalance between cylinders, characteristic of the normal operation of an engine under service conditions.

2.2.4 Whilst limits for torsional vibration stress in crankshafts are no longer stated explicitly, calculations are to include estimates of crankshaft stress at all designated operating/service speeds, as well as at any major critical speed.

2.2.5 Calculations are to take into account the possible effects of excitation from propeller rotation. Where the system shows some sensitivity to this phenomenon, propeller makers' data should be used as a basis for calculation, and submitted.

2.2.6 Where the torsional stiffness of flexible couplings varies with torque, frequency or speed, calculations should be representative of the appropriate range of effective dynamic stiffness.

■ *Section 3* **Design**

3.1 Symbols and definitions

3.1.1 The symbols used in this Section are defined as follows:

d = minimum diameter of shaft considered, in mm

r = ratio N/N_s or N_c/N_s whichever is applicable

N = engine speed, in rev/min

N_c = critical speed, in rev/min

N_s = maximum continuous engine speed, in rev/min, or, in the case of constant speed generating sets, the full load speed, in rev/min

Q_s = rated full load mean torque

τ_c = maximum value of the vibration stress for continuous running at or below the maximum speed, in N/mm^2

τ_t = permissible stress due to torsional vibrations for transient operation, in N/mm^2

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2

C_k = a factor for different shaft design features, *see* Table 1.3.1

C_d = a size factor defined as $0,35 + 0,93d^{-0,2}$

k = the factor used in determining minimum shaft diameter, defined in Pt 11, Ch 2,4.2.1 and 4.4.3.

Table 1.3.1 C_k factors

For intermediate shafts with			For thrust shafts external to engines		For propeller shafts
Integral coupling flanges	Shrink fit couplings	Keyways	On both sides of thrust collar	In way of axial bearing where a roller bearing is used as a thrust bearing	For which k = 1,22 and = 1,26
1,0	1,0	0,60	0,85	0,85	0,55

NOTE
The determination of C_k – factors for shafts other than shown in this Table is at the discretion of LR.

3.1.2 Alternating torsional vibration stresses are to be based on half-range amplitudes of stress resulting from the alternating torque (which is superimposed on the mean torque) representing the synthesis of all harmonic orders present.

3.1.3 All vibration stress limits relate to the synthesis or measurement of total nominal torsional stress and are to be based on the plain section of the shafting neglecting stress raisers.

3.2 Limiting stress in propulsion shafting

3.2.1 The following stress limits apply to intermediate shafts, thrust shafts and to screwshafts fully protected from seawater. For screwshafts, the limits apply to the minimum section between the forward end of the propeller boss and the forward stern gland.

3.2.2 In the case of unprotected screwshafts, special consideration will be given.

3.2.3 In no part of the propulsion shafting system may the alternating torsional vibration stresses exceed the values of τ_c for continuous operation, and τ_t for transient running, given by the following formulae:

$$\tau_c = \frac{\sigma_u + 160}{18} C_k C_d (3 - 2r^2) \text{ for } r < 0,9 \quad \text{N/mm}^2$$

$$\tau_c = \frac{\sigma_u + 160}{18} C_k C_d \, 1,38 \text{ for } 0,9 \le r \le 1,05 \quad \text{N/mm}^2$$

$$\tau_t = \pm\, 1,7\tau_c \frac{1}{\sqrt{C_k}} \text{ for } r \le 0,8$$

3.2.4 In general, the tensile strength of the steel used is to comply with the requirements of Pt 11, Ch 2. For the calculation of the permissible limits of stresses due to torsional vibration, σ_u is not to be taken as more than 800 N/mm^2 in the case of intermediate shafts and 600 N/mm^2 in the case of thrust and propeller shafts.

3.2.5 Where the scantlings of coupling bolts and straight shafting differ from the minimum required by the Rules, special consideration will be given.

3.3 Generator sets

3.3.1 Natural frequencies of the complete set are to be sufficiently removed from the firing impulse frequency at the full load speed, particularly where flexible couplings are interposed between the engine and generator.

3.3.2 Within the speed limits of $0,95N_s$ and $1,05N_s$ the vibration stresses in the transmission shafting are not to exceed the values given by the following formula:

$$\tau_c = \pm\, (21 - 0,014d) \quad \text{N/mm}^2.$$

3.3.3 Vibration stresses in the transmission shafting due to critical speeds which have to be passed through in starting and stopping, are not to exceed the values given by the following formula:

$\tau_t = 5{,}5\tau_c$.

3.3.4 The amplitudes of total vibratory inertia torques imposed on the generator rotors are to be limited to $\pm 2{,}0Q_s$ in general, or to $\pm 2{,}5Q_s$ for close-coupled revolving field alternating current generators, over the speed range from $0{,}95N_s$ to $1{,}05N_s$. Below $0{,}95N_s$ the amplitudes are to be limited to $\pm 6{,}0Q_s$. Where two or more generators are driven from one engine, each generator is to be considered separately in relation to its own rated torque.

3.3.5 The rotor shaft and structure are to be designed to withstand these magnitudes of vibratory torque. Where it can be shown that they are capable of withstanding a higher vibratory torque, special consideration will be given.

3.3.6 In addition to withstanding the vibratory conditions over the speed range from $0{,}95N_s$ to $1{,}05N_s$ flexible couplings, if fitted, are to be capable of withstanding the vibratory torques and twists arising from transient criticals and short-circuit currents.

3.3.7 In the case of alternating current generators, resultant vibratory amplitudes at the rotor are not to exceed ±3,5 electrical degrees under both full load working conditions and the malfunction condition mentioned in 2.2.3.

3.4 Other auxiliary machinery systems

3.4.1 The relevant requirements of 3.3.1, 3.3.2 and 3.3.3 are also applicable to other machinery installations such as pumps or compressors.

3.5 Other machinery components

3.5.1 **Torsional vibration dampers**. The use of dampers or detuners to limit vibratory stress due to resonances which occur within the range between $0{,}85N_s$ and $1{,}05N_s$ are to be considered. If fitted, these should be of a type which makes adequate provision for dissipation of heat. Where necessary, performance monitoring may be required.

3.5.2 **Flexible couplings**:

(a) Flexible couplings included in an installation are to be capable of transmitting the mean and vibratory loads without exceeding the makers' recommended limits for angular amplitude or heat dissipation.

(b) Where calculations indicate that the limits recommended by the manufacturer may be exceeded under misfiring conditions, a suitable means is to be provided for detecting and indicating misfiring. Under these circumstances power and/or speed restriction may be required. Where machinery is non-essential, disconnection of the branch containing the coupling would be an acceptable action in the event of misfiring.

3.5.3 **Gearing**:

(a) The torsional vibration characteristics are to comply with the requirements of 2.2. The vibratory torque should not exceed one-third of the full transmission torque throughout the speed range. In cases where the proposed transmission torque loading on the gear teeth is less than the maximum allowable, special consideration will be given the acceptance of additional vibratory loading on the gears.

(b) Where calculations indicate the possibility of torque reversal, the operating speed range is to be determined on the basis of observations during sea trials.

3.6 Restricted speed and/or power ranges

3.6.1 Restricted speed and/or power ranges will be imposed where the stresses exceed the limiting values, τ_c, for continuous running. Similar restrictions will be imposed, or other protective measures required to be taken, where vibratory torques or amplitudes are considered to be excessive for particular machinery items.

3.6.2 Critical responses which give rise to speed restrictions are to be arranged sufficiently removed from the maximum revolutions per minute to ensure that, in general, at $r = 0{,}8$ the stress due to the upper flank does not exceed τ_c.

3.6.3 Where shafting stresses due to a torsional critical response exceed the limiting values, τ_c, for continuous running, the speed restriction will be from:

$$= \frac{16}{18 - r} N_c \text{ to } \frac{18 - r}{16} N_c \text{ inclusive.}$$

3.6.4 Where calculated vibration stresses due to criticals below $0{,}8N_s$ marginally exceed τ_c or where the critical speeds are sharply tuned, the range of revolutions restricted for continuous operation may be reduced.

3.6.5 In cases where the resonance curve of a critical speed has been derived from measurements, the range of revolutions to be avoided for continuous running may be taken as that over which the measured stresses are in excess of τ_c, having regard to tachometer accuracy.

3.6.6 Where restricted speed ranges under normal operating conditions are imposed, notice boards are to be fitted at the control stations stating that the engine is not to be run continuously between the speed limits obtained as above, and the engine tachometers are to be marked accordingly.

3.6.7 Where vibration stresses approach the limiting value, τ_t, the range of revolutions restricted for continuous operation may be extended. The notice boards are to indicate that this range must be passed through rapidly.

3.6.8 For excessive vibratory torque, stress or amplitude in other components, based on 3.6.1 to 3.6.3, the limits of any speed/power restriction are to be such as to maintain acceptable levels during continuous operation.

3.6.9 Where the restrictions are imposed for the contingency of an engine malfunction or component failure, the limits are to be entered in the machinery operating manual.

3.6.10 There are to be no restricted speed ranges imposed above a speed ratio of $r \geq 0,8$ under normal operating conditions.

3.7 Tachometer accuracy

3.7.1 Where restricted speed ranges are imposed as a condition of approval, the tachometer accuracy is to be checked against the counter readings, or by equivalent means, in the presence of the Surveyors to verify that it reads correctly within ±2 per cent in way of the restricted range of revolutions.

3.8 Governor control

3.8.1 Where there is significant critical response above and close to the service speed, consideration will be given to the effect of temporary overspeed.

■ *Section 4* Measurements

4.1 General requirements

4.1.1 Where calculations indicate that the limits for torsional vibration within the range of working speeds are exceeded, measurements, using an appropriate technique, may be taken from the machinery installation for the purpose of approval of torsional vibration characteristics, or determining the need for restricted speed ranges and the confirmation of their limits.

4.1.2 Where differences between calculated and measured levels of stress, torque or angular amplitude arise, the stress limits are to be applied to the stresses measured on the completed installation.

4.1.3 The method of measurement is to be appropriate to the machinery components and the parameters which are of concern. Where shaft stresses have been estimated from angular amplitude measurements, and are found to be close to limits, strain gauge techniques may be required. When measurements are required, detailed proposals are to be submitted.

4.2 Vibration monitoring

4.2.1 Where calculations and/or measurements have indicated the possibility of excessive vibratory stresses, torques or angular amplitudes in the event of a malfunction, vibration or performance monitoring, directly or indirectly, may be required.

■ *Section 5* Requirements for craft which are not required to comply with the HSC Code

5.1 General requirements

5.1.1 The requirements of this Chapter do not apply to the following types of vessel having main engines not exceeding 500 kW power output or auxiliary engines not exceeding 110 kW output for essential services:
(a) Service craft of less than 24 m.
(b) Yachts.
(c) ACVs.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of Parts 9, 10, 11 and 12.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to the following systems:

- Main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, *P*, in kW, and revolutions per minute, *R*, are referred to, the values to be used are those defined in Part 9.

1.3 Basic requirements

1.3.1 For all main propulsion systems, the Builders are to ensure that axial vibration amplitudes are satisfactory throughout the speed range. Where natural frequency calculations indicate significant axial vibration responses, sufficiently wide restricted speed ranges will be imposed. Alternatively, measurements may be used to determine the speed ranges at which amplitudes are excessive for continuous running.

■ *Section 2* Details to be submitted

2.1 Particulars to be submitted

2.1.1 The results of calculations, together with recommendations for any speed restrictions found necessary.

2.1.2 The Enginebuilder's recommendation for axial vibration amplitude limits.

2.1.3 Estimate of flexibility of the thrust bearing and its supporting structure.

2.2 Scope of calculations

2.2.1 Calculations of axial vibration natural frequency are to be carried out using appropriate techniques, taking into account the effects of flexibility of the thrust bearing, for shaft systems where the propeller is:

(a) Driven directly by a reciprocating internal combustion engine.

(b) Driven via gears, or directly by an electric motor, and where the total length of shaft between propeller and thrust bearing is in excess of 60 times the intermediate shaft diameter.

2.2.2 Where an axial vibration damper is fitted, the calculations are to consider the effect of a malfunction of the damper.

■ *Section 3* Design

3.1 Symbols

3.1.1 The symbols used in this Section are as follows:

D = outside diameter of shaft, taken as an average over length l, in mm

d = internal diameter of shaft, in mm

l = length of shaft line between propeller and thrust bearing, in mm

m = mass of shaft line considered, in kg
= $0{,}785\,(D^2 - d^2)\,G\,l$

M = dry mass of propeller, in kg

$A = \dfrac{m}{M}$

M_e = $M\,(A + 2)$

n = number of propeller blades

k = estimated stiffness at thrust block bearing, in N/m

E = modulus of elasticity of shaft material, in N/mm^2

G = density of shaft material, in kg/mm^3

N_c = critical speed, in rev/min.

3.2 Critical frequency of axial vibration

3.2.1 For those systems as defined in 2.2.1(b) the propeller speed at which the critical frequency occurs may be estimated using the following formula:

$$N_c = \frac{0{,}98}{n} \left(\frac{ab}{a + b} \right)^{1/2} \text{ rev/min}$$

where

$$a = \frac{E}{G\,l^2} (66{,}2 + 97{,}5A - 8{,}88A^2)^2 \quad \text{c/min}^2$$

$$b = 91{,}2 \frac{k}{M_e} \quad \text{c/min}^2.$$

3.2.2 Where the results of this method indicate the possibility of an axial vibration resonance in the vicinity of the service speed, calculations using a more accurate method will be required.

3.3 Restricted speed ranges

3.3.1 The limits of any speed restriction are to be such as to maintain axial amplitudes within recommended levels during continuous operation.

3.3.2 Limits of a speed restriction, where required, may be determined from calculation or on the basis of measurement.

3.3.3 Where a speed restriction is imposed for the contingency of a damper malfunction, the speed limits are to be entered in the operating manual and regular monitoring of the axial vibration amplitude is required. Details of proposals for monitoring are to be submitted.

■ *Section 4* Measurements

4.1 General requirements

4.1.1 Where calculations indicate the possibility of excessive axial vibration amplitudes within the range of working speeds under normal or malfunction conditions, measurements are required to be taken from the shafting system for the purpose of determining the need for restricted speed ranges.

4.2 Vibration monitoring

4.2.1 Where a vibration monitoring system is to be specified, details of proposals are to be submitted.

■ *Section 5* Requirements for craft which are not required to comply with the HSC Code

5.1 General requirements

5.1.1 The requirements of this Chapter do not apply to the following types of vessel having main engines not exceeding 500 kW power output or auxiliary engines not exceeding 110 kW output for essential services:

(a) Service craft of less than 24 m.

(b) Yachts.

(c) ACVs.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of Parts 9, 10, 11 and 12.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to the following systems:

- Main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, *P*, in kW, and revolutions per minute, *R*, are referred to, the values to be used are those defined in Part 9.

1.3 Basic requirements

1.3.1 For all main propulsion shafting systems, the Builders are to ensure that lateral vibration characteristics are satisfactory throughout the speed range.

■ *Section 2* Details to be submitted

2.1 Particulars to be submitted

2.1.1 Calculations of the lateral vibration characteristics of shafting systems having supports outboard of the hull or incorporating cardan shafts are to be submitted.

2.2 Calculations

2.2.1 The calculations in 2.1.1, taking account of bearing, oil-film (where applicable) and structural dynamic stiffnesses, are to investigate the excitation frequencies which may result in significant amplitudes within the speed range, and are to indicate relative deflections and bending moments throughout the shafting system.

■ *Section 3* Measurements

3.1 General requirements

3.1.1 Where calculations indicate the possibility of significant lateral vibration responses within the range of working speeds, measurements using an appropriate recognized technique may be required to be taken from the shafting system for the purpose of determining that hazardous whirling or excessive vibration does not occur.

3.1.2 The method of measurement is to be appropriate to the machinery arrangement and the modes of vibration which are of concern. When measurements are required, detailed proposals are to be submitted in advance.

■ *Section 4* Requirements for craft which are not required to comply with the HSC Code

4.1 General requirements

4.1.1 The requirements of this Chapter do not apply to the following types of vessel having main engines not exceeding 500 kW power output unless the spacing of bearings on the propulsion shafting exceeds 30 diameters or cardan shafts are used in the propulsion shafting system:

(a) Service craft of less than 24 m.
(b) Yachts.
(c) ACVs.

Section 1
Shaft alignment

1.1 General

1.1.1 The Builder is to carry out shaft alignment calculations for all installations and to prepare alignment procedures detailing the proposed alignment method and the alignment checks.

1.2 Particulars to be submitted for approval – Shaft alignment calculations

1.2.1 Shaft alignment calculations are to be submitted to Lloyd’s Register (hereinafter referred to as ‘LR’) for approval for the following shafting systems where the screwshaft has a diameter of 250 mm or greater in way of the aftermost sterntube bearing:

(a) All geared installations.
(b) Installations with one shaftline bearing, or less, inboard of the forward sterntube bearing.
(c) Where prime movers or shaftline bearings are installed on resilient mountings.

1.2.2 The shaft alignment calculations are to take into account the:

(a) thermal displacements of the bearings between cold static and hot dynamic machinery conditions;
(b) buoyancy effect of the propeller immersion due to the craft's operating draughts;
(c) effect of predicted hull deformations over the range of the craft's operating draughts, where known;
(d) gear forces, where appropriate;
(e) for multi-engined installations, possible contributions in the mode of operation;
(f) propeller offset thrust effects, where applicable;
(g) bearing loading in the horizontal plane, where appropriate; and
(h) bearing weardown, where applicable, and its effect on the bearing loads.

1.2.3 The shaft alignment calculations are to state the:

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the craft's operating profile, for the machinery in cold and hot, static and dynamic conditions;
(b) bearing influence coefficients and the deflection, slope, bending moment and shear force along the shaftline;
(c) details of propeller offset thrust effects, where employed in calculation;
(d) details of proposed slope-bore of the aftermost sterntube bearing, where applicable;
(e) manufacturer's specified limits for bending moment and shear force at the shaft couplings of the gearbox/prime movers;
(f) estimated bearing weardown rates for water or grease-lubricated sterntube bearings;
(g) origin of findings where the effect of hull deformation has been considered, *viz*. whether finite element calculations or measured results from sister or similar craft have been used;
(h) anticipated thermal rise of prime movers and gearing units between cold static and hot running conditions; and
(j) manufacturer's allowable bearing loads.

1.3 Particulars to be submitted for review – Shaft alignment procedure

1.3.1 A shaft alignment procedure is to be submitted for all main propulsion installations detailing, as a minimum, the:

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the craft's operating profile, for the machinery in cold and hot, static and dynamic conditions;
(b) maximum permissible loads for the proposed bearing designs;
(c) design bearing offsets from the straight line;
(d) design gaps and sags;
(e) location and loads for the temporary shaft supports;
(f) expected relative slope of the shaft and the bearing in the aftermost sterntube bearing;
(g) details of slope-bore of the aftermost sterntube bearing, where applied;
(h) expected shear forces and bending moments at the forward end flange of the shafting system connecting to the gear output shaft or, for direct-drive installations, to the prime mover output flange;
(j) proposed bearing load measurement technique and its estimated accuracy;
(k) jack correction factors for each bearing where the bearing load is measured using a specified jacking technique;
(l) proposed shaft alignment acceptance criteria, including the tolerances; and
(m) flexible coupling alignment criteria.

1.4 Design and installation criteria

1.4.1 For main propulsion installations, the shafting is to be aligned to give, in all conditions of craft loading and machinery operation, bearing load distribution satisfying the requirements of 1.4.2.

1.4.2 Design and installation of the shafting is to satisfy the following criteria:

(a) The Builder is to position the bearings and construct the bearing seatings to minimize the effects of hull deflections under any of the craft's operating conditions.
(b) Relative slope between the propeller shaft and the aftermost sterntube bearing is, in general, not to exceed 3×10^{-4} rad.
(c) Sterntube bearing loads are to satisfy the requirements of Pt 11, Ch 2,4.16.2.

(d) Intermediate shaft bearings' loads are not to exceed 80 per cent of the bearing manufacturer's allowable maximum load, for plain journal bearings, based on the bearing projected area.
(e) Main gear wheel bearing loads are to be within the gear-box manufacturer's specified limits.
(f) Resulting shear forces and bending moments are to meet the equipment manufacturer's specified coupling conditions throughout the shafting system.
(g) The manufacturer's radial, axial and angular alignment limits for the flexible couplings are to be maintained.

1.5 Measurements

1.5.1 Where calculations indicate that the system is sensitive to changes in alignment under different service conditions, the optimized shaft alignment is to be verified by measurements during sea trials using an approved strain gauge technique.

1.6 Flexible couplings

1.6.1 Where the shafting system incorporates flexible couplings, the effects of such couplings on the various modes of vibration are to be considered, *see* Section 2.

■ *Section 2* Requirements for craft which are not required to comply with the HSC Code

2.1 General requirements

2.1.1 The requirements of Section 1 do not apply to the following types of vessel where the main engine does not exceed 500 kW power output:
(a) Service craft of less than 24 m.
(b) Yachts.
(c) ACVs.

2.1.2 The engines, shafting, sterntubes and propeller brackets are to be carefully fitted and well secured to the hull of the craft so that satisfactory alignment of the shafting will be maintained in service.

2.1.3 The alignment of the sterntube and propeller brackets is to be demonstrated before launching and the shafting and engine alignment verified when afloat.

RULES AND REGULATIONS FOR THE CLASSIFICATION OF SPECIAL SERVICE CRAFT

STEERING SYSTEMS

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PART 14

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Chapter Contents Part 14

Contents

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 The requirements of this Chapter apply to the design and construction of steering systems.

(a) A steering system includes:
- all steering devices;
- all mechanical, electrical, and hydraulic linkages;
- all power devices, including manual devices;
- all controls and all actuating systems.

(b) Steering may be achieved by means of:
- air or water rudders;
- foils, flaps, steerable propellers or jets;
- yaw control ports or transverse thrusters;
- differential propulsive thrust;
- variable geometry of the craft or its lift system components; or
- by a combination of these devices.

1.2 Provision of steering gear

1.2.1 Craft are to be provided with a means for steering which is to be of adequate strength and suitable design to enable the craft's heading and direction of travel to be effectively controlled at all designed operating conditions.

1.2.2 Craft are to be provided with a main steering system and an independent auxiliary steering unit. The main and the auxiliary steering units are to be so arranged that the failure of one of them will not render the other one inoperative or unable to bring the craft to a safe situation.

1.2.3 An auxiliary steering system is not a requirement provided the craft is fitted with two independent and identical steering systems, one of which is capable of steering the craft when the second system becomes inoperative.

1.3 Definitions

1.3.1 **Main steering system** means the machinery, the actuator(s), the power units, if any, ancillary equipment, and the means of applying the steering torque, if applicable, necessary for the purpose of steering the craft under design conditions.

1.3.2 **Auxiliary steering system** means the equipment other than any part of the main steering unit necessary to steer the craft in the event of failure of the main steering system.

1.3.3 **Steering power system** means:

(a) In the case of electric steering system, an electric motor and its associated electrical parts.

(b) In the case of electrohydraulic steering system, an electric motor and its associated electrical parts and connected pump.

(c) In the case of other hydraulic steering system units, a driving engine and connected pump.

1.3.4 **Steering control system** means the equipment by which orders are transmitted from the control station to the steering power units. Steering control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

1.3.5 **Maximum working pressure** means the expected pressure in the system when the steering unit is operated under the most onerous design condition.

■ *Section 2* Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the plans and information as detailed in 2.2 and 2.3 are to be submitted.

2.2 Plans

2.2.1 Detailed plans of all load bearing, and torque transmitting components and hydraulic pressure retaining parts of the steering system together with proposed rated torque, all relief valve settings, and scantlings.

2.2.2 Schematic of the hydraulic systems, together with pipe material, relief valve and working pressures.

2.2.3 Details of control engineering aspects in accordance with Pt 16, Ch 1.

2.3 Calculations and information

2.3.1 The manoeuvring characteristics for which the craft has been designed.

2.3.2 Material specifications.

■ *Section 3* Materials

3.1 General

3.1.1 All components are to be in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 All steering unit components transmitting mechanical forces are to be of steel or other approved ductile material. In general, such material is to have an elongation of not less than 12 per cent nor a tensile strength in excess of 650 N/mm^2. Special consideration will be given to the acceptance of grey cast iron for low pressure valve bodies and mechanical parts with low stress levels.

3.1.3 Consideration will be given to the acceptance of non-ferrous materials as applicable.

■ *Section 4* Design and performance

4.1 General

4.1.1 Power-operated steering units are to be provided with positive arrangements, such as limit switches, for stopping the unit before the mechanical stops are reached. These arrangements are to be synchronised with the unit itself and not with the steering unit control mechanism.

4.1.2 The steering unit is to be secured to the seating by fitted bolts, and suitable chocking arrangements are to be provided. The seating is to be of substantial construction.

4.1.3 All welded joints within the pressure boundary of an actuator or connecting parts transmitting mechanical loads are to be of full penetration type or of equivalent strength.

4.1.4 Steering devices involving variable geometry of the craft or its lift system components are to be so constructed that any failure of the drive linkage or actuating system will not significantly hazard the craft.

4.2 Actuating systems

4.2.1 Actuators are to be designed in accordance with the relevant requirements of Part 15 for Class I pressure vessels (notwithstanding any exemptions for hydraulic cylinders).

4.2.2 Accumulators, if fitted, are to comply with the relevant requirements of Part 15.

4.2.3 The design pressure for calculations to determine the scantlings of piping and other steering components subjected to internal hydraulic pressure shall be at least 1,25 times the maximum working pressure to be expected under the operational conditions specified taking into account any pressure which may exist in the low pressure side of the system. Fatigue criteria may be applied for the design of piping and components, taking into account pulsating pressures due to dynamic loads.

4.2.4 The permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{\sigma_B}{A} \text{ or } \frac{\sigma_y}{B}$$

where

σ_B = specified minimum tensile strength of material at ambient temperature

σ_y = specified minimum yield stress or 0,2 per cent proof stress of the material, at ambient temperature.

A and *B* are given by the following Table:

	Wrought steel	Cast steel	Nodular cast iron
A	3,5	4	5
B	1,7	2	3

4.2.5 Oil seals between non-moving parts, forming part of the external pressure boundary, should be of the metal upon metal type or of an equivalent type.

4.2.6 Hydraulic power operated steering units are to be provided with the following:

(a) Arrangements to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system;

(b) A fixed storage tank having sufficient capacity to recharge at least one power actuating system including the reservoir. The storage tank is to be provided with a contents gauge and be permanently connected by piping in such a manner that the hydraulic systems can be readily recharged from a position within the steering unit compartment, if applicable.

4.3 Rudder systems

4.3.1 For the requirements of rudder and rudder stock, *see* Pt 3, Ch 3.

4.3.2 Tillers and quadrants are to comply with the requirements of Table 1.4.1.

4.3.3 On double rudder installations, where the two tillers are connected by mechanical means (tie-bar), the strength and stability of the tie-bar is to be assessed using the maximum steering torque applied to the stock.

4.3.4 Where higher tensile steel bolts are used on bolted tillers and quadrants, the yield and ultimate tensile stresses of the bolt material are to be stated on plans submitted for approval, together with full details of the methods to be adopted to obtain the required setting-up stress. Where proprietary nuts or systems are used, the manufacturer's instructions for assembly are to be adhered to.

Table 1.4.1 Connection of tiller to stock

(1) Dry fit – tiller to stock for M_T (*see* Notes)	(a) For keyed connection, factor of safety against slippage = 1,1 (b) For keyless connection, factor of safety against slippage = 2,2 (c) Coefficient of friction = 0,17 (d) Grip stress not to be less than 20 N/mm^2
(2) Hydraulic fit – tiller to stock for M_T (*see* Notes)	(a) For keyed connection, factor of safety against slippage = 1,1 (b) For keyless connection, factor of safety against slippage = 2,2 (c) Coefficient of friction = 0,12 (d) Grip stress not to be less than 20 N/mm^2
(3) Bolted tiller and quadrant (*see* Symbols and Notes)	Shim to be fitted between two halves before machining to take rudder stock, then removed prior to fitting Minimum thickness of shim: For 4 connecting bolts: $t_s = 0{,}0014 d_{SU}$ mm For 6 connecting bolts: $t_s = 0{,}0012 d_{SU}$ mm Key to be fitted Diameter of bolts, $\delta_T = \dfrac{0{,}60 d_{SU}}{\sqrt{n_T}}$ mm Distance from centre of stock to centre of bolts should generally be equal to $d_{SU}\left(1{,}0 + \dfrac{0{,}30}{\sqrt{n_T}}\right)$ mm Thickness of flange on each half of the bolted tiller $\dfrac{0{,}66 d_{SU}}{\sqrt{n_T}}$ mm
(4) Key (*see* Symbols and Notes)	Effective sectional area in shear $\geq 0{,}25 d_{SU}^2$ mm^2 Key thickness $\geq 0{,}17 d_{SU}$ mm Keyway is to extend over full depth of tiller and is to have a rounded end. Corners are to be provided with suitable radii to avoid high stress at the keyway root.
(5) Section modulus – tiller arm (at any point within its length about vertical axis) (*see* Symbols and Notes)	To be not less than the greater of: (a) $Z_{TA} = \dfrac{0{,}15 d_{SU}^3 (b_T - b_s)}{1000 b_T}$ cm^3 (b) $Z_{TA} = \dfrac{0{,}06 d_{SU}^3 (b_T - 0{,}9 d_{SU})}{1000 b_T}$ cm^3 If more than one arm is fitted, combined modulus is not to be less than the greater of (a) or (b). For solid tillers, the breadth to depth ratio is not to exceed 2.
(6) Boss (*see* Symbols and Notes)	Depth of boss $\geq d_{SU}$ Thickness of boss in way of tiller $\geq 0{,}4 d_{SU}$

Symbols

b_s = distance between the section of the tiller arm under consideration and the centre of the rudder stock, in mm
NOTE: b_T and b_s are to be measured with zero rudder angle
b_T = distance from the point of application of the load on the tiller to the rudder stock, in mm
n_T = number of bolts in coupling, but generally not to be taken greater than six
t_s = thickness of shim for machining bolted tillers and quadrants, in mm
Z_{TA} = section modulus of tiller arm, in cm^3
d_{SU} = *see* Pt 3, Ch 3
δ_T = diameter of bolts securing bolted tillers and quadrants, in mm
σ_o = minimum yield stress or 0,5 per cent proof stress of the tiller bolt material, in N/mm^2

NOTES
1. If d_{SU} > 400 mm, higher tensile steel bolts are to be used for bolted tillers. A predetermined setting-up load equivalent to a stress of approximately $0{,}7\sigma_o$ should be applied to each bolt assembly. A lower stress may be accepted provided that two keys, complying with item (4) are fitted.
2. Where M_T, the maximum turning moment applied to the stock, is to be taken as the greater of the following:
   (a) $11{,}1 d_{SU}^3$ Nmm where d_{SU} is to be determined from Table 3.2.7 in Pt 3, Ch 3 with σ_o taken as 235 N/mm^2 and $N = 0$.
   (b) The torque generated by the steering gear at the maximum working pressure, *see* 1.3.5.

4.3.5 All steering components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of the tiller.

4.3.6 In bow rudders having a vertical locking pin operated from the deck above, positive means are to be provided to ensure that the pin can be lowered only when the rudder is exactly central. In addition, an indicator is to be fitted at the deck to show when the rudder is exactly central.

4.4 Performance

4.4.1 The main steering system is to be:

(a) Of adequate strength and capable of steering the craft at all speeds and conditions for which the craft is designed and this shall be demonstrated during trials;
(b) operated by power where necessary to meet the requirements of (a) and in any case when the Rules require a rudder stock over 120 mm diameter in way of the tiller; and
(c) so designed that it will not be damaged at maximum astern speed.

4.4.2 The auxiliary steering system is to be:

(a) Of adequate strength and capable of steering the craft at navigable speed and of being brought speedily into action in an emergency.
(b) Operated by power where necessary to meet the requirements of (a) and in any case when the Rules, require a rudder stock over 230 mm diameter in way of the tiller.
(c) Where manual operated steering units are proposed, these are acceptable when the operation does not require an effort exceeding 160N under normal conditions.

4.4.3 Main and auxiliary steering power units are to be:

(a) Arranged to re-start automatically when power is restored after power failure.
(b) Capable of being brought into operation from a position at the control station. In the event of a power failure to any one of the steering power units, an audible and visual alarm is to be given on the control station.
(c) Arranged so that transfer between units can be readily effected.

4.4.4 For high speed craft, in the event of total power failure, either:

(a) emergency power for steering systems/drives is to be restored automatically within five seconds. To achieve this an interim fast acting system may be required to come into operation until such time as auxiliary/ emergency power source comes on line. (Note: starting arrangements are to comply with the requirements relating to starting arrangements of emergency generators); or
(b) means are to be provided to bring the craft to a safe condition.

4.4.5 Where the steering unit is so interconnected that more than one power system, or control system, can be simultaneously operated, the design is to be such that hydraulic locking caused by a single failure cannot occur.

4.4.6 Steering systems, other than of the hydraulic type, will be accepted provided the standards are considered equivalent to the requirements of this Section.

■ *Section 5* Piping systems

5.1 Components

5.1.1 Piping, joints, valves, flanges and other fittings are to comply within the requirements of Pt 15, Ch 1 for Class 1 piping system components. The design pressure is to be in accordance with 4.2.3.

5.2 Valve and relief valve arrangements

5.2.1 For vessels with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

5.2.2 Arrangements for bleeding air from the hydraulic system are to be provided, where necessary.

5.2.3 Relief valves are to be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The settings of the relief valves is not to exceed the design pressure. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

5.2.4 Relief valves for protecting any part of the hydraulic system which can be isolated, as required by 5.2.3 are to comply with the following:

(a) The setting pressure is not to be less than 1,25 times the maximum working pressure.
(b) The minimum discharge capacity of the relief valve(s) is not to be less than 110 per cent of the total capacity of the pumps which can deliver through it (them).
Under such conditions the rise in pressure is not to exceed 10 per cent of the setting pressure. In this regard, due consideration is to be given to extreme foreseen ambient conditions in respect of oil viscosity.

5.3 Flexible hoses

5.3.1 Flexible hoses are to be of approved type, *see* Pt 15, Ch 1,13.

Section 6
Control, monitoring and electrical equipment

6.1 Control

6.1.1 All steering systems are to be be operated from the craft's control station.

6.1.2 If steering systems can also be operated from other positions, then two-way communication is to be arranged between the control station and these other positions.

6.1.3 Steering control is to be provided:

(a) For the main steering unit, both at the control station and in the steering unit compartment, where applicable;

(b) Where the main steering unit is arranged by two independent control systems, both operable from the control station. This does not require duplication of the steering wheel or steering lever. Where the control system consists of a hydraulic telemotor, a second independent system need not be fitted.

(c) For the auxiliary steering unit, in the steering unit compartment and, if power operated, it is also to be operable from the control station and is to be independent of the control system for the main steering system.

6.1.4 Electrical control systems are to be independent and separated as far as is practicable throughout their length.

6.1.5 Any main and auxiliary steering unit control system operable from the control station is to comply with the following:

(a) Means are to be provided in the steering unit compartment, if applicable, for disconnecting any control system operable at the control station from the steering unit it serves;

(b) The system is to be capable of being brought into operation from a position on the control station.

6.1.6 Appropriate operating instructions with a block diagram showing the change-over procedures for steering unit control systems and steering unit actuating systems are to be permanently displayed at the control station and in the steering unit compartment, if applicable.

6.1.7 Where the system failure alarms for hydraulic lock, *see* Table 1.6.1, are provided, appropriate instructions are to be placed on the control station to shut down the system at fault.

6.2 Monitoring

6.2.1 Alarms and monitoring requirements are indicated in 6.2.2, 6.2.3 and Table 1.6.1.

Table 1.6.1 Alarms

Item	Alarm	Note
Angular position of the Steering Mechanism	—	Indication, *see* 6.2.2
Steering power units, power	Failure	—
Steering motors	Overload Single phase	For alarm and running indication locations. *see* 6.3.2 and 6.3.3
Control system power	Failure	—
Steering gear hydraulic oil level	Low	Each reservoir to be be monitored. For Alarm locations, *see* 6.3.4.
Auto pilot	Failure	Running indication
Hydraulic oil temperature	High	Where oil cooler is fitted
Hydraulic lock	Fault	Where more than one system (either power or control) can be operated simultaneously each each system is to be monitored, *see* Note
Hydraulic oil filter differential pressure	High	When oil filters are fitted

NOTE
This alarm is to identify the system at fault and is to be activated when (for example):
- position of the variable displacement pump control system does not correspond with given order; or
- incorrect position of 3-way full flow valve or similar in constant delivery pump system is detected.

6.2.2 The angular position of the steering mechanism is to:

(a) Where the main steering unit is power operated, be indicated at the control station, and other positions as applicable. The angular indication is to be independent of the steering unit control system; and is to indicate any abnormal responses or malfunctions. The logic of such feedback and indications are to be consistent with the other alarms and indications so that in an emergency operators are unlikely to be confused.

(b) Be recognizable in the steering unit compartment, if applicable.

6.2.3 The alarms described in Table 1.6.1 are to be indicated on the navigating bridge and the additional locations described and are to be in accordance with the alarm system specified by Pt 16, Ch 1,2.3.

6.3 Electrical equipment

6.3.1 Short circuit protection, and overload alarm and, in the case of polyphase circuits, an alarm to indicate failure of any one of the phases is to be provided for each main and auxiliary motor circuit. Protective devices are to operate at not less than twice the full load current of the motor or circuit protected and are to allow excess current to pass during the normal accelerating period of the motors.

6.3.2 The alarms required by 6.3.1 are to be provided on the bridge and in the main machinery space or control room from which the main machinery is normally controlled.

6.3.3 Indicators for running indication of each main and auxiliary motor are to be installed on the control station and at a suitable main machinery control position.

6.3.4 A low-level alarm is to be provided for each steering system hydraulic fluid reservoir to give the earliest practicable indication of hydraulic fluid leakage. Alarms are to be given on the navigation bridge and in the machinery space where they can be readily observed.

6.3.5 Two exclusive circuits are to be provided for each electric or electrohydraulic steering unit arrangement consisting of one or more electric motors.

6.3.6 Each of these circuits is to be fed from the main switchboard. One of these circuits may pass through the emergency switchboard.

6.3.7 One of these circuits may be connected to the motor of an associated auxiliary electric or electrohydraulic power unit.

6.3.8 Each of these circuits is to have adequate capacity to supply all the motors which can be connected to it and which can operate simultaneously.

6.3.9 These circuits are to be separated throughout their length as widely as is practicable.

6.3.10 Each main and auxiliary electric control system which is to be operated from the control station is to comply with the following:

(a) It is to be served with electric power by a separate circuit supplied from the associated steering unit power circuit, from a point within the steering unit compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering unit power circuit is connected.

(b) Each separate circuit is to be provided with short circuit protection only.

■ *Section 7* Requirements for craft which are not required to comply with the HSC Code

7.1 Introduction

7.1.1 In craft over 50 m in length, the main steering gear is to be power operated.

7.1.2 Service craft of length 50 m or less, or sailing yachts of length 50 m or less, may have manual steering. Where wheel steering is fitted an alternative means of steering (which may be a hand tiller) is to be readily available, and the performance of both systems is to be in accordance with 7.2.6.

7.2 Design and performance

7.2.1 The main steering gear is to be capable of steering the craft at the maximum ahead speed and turning the rudder from hardover to hardover in 30 seconds.

7.2.2 Where wire rope steering leads are fitted, they are to be of suitable construction. Wire rope is to be stainless steel or suitably protected against corrosion and the strength of the rope is to be as follows:

$$\text{Breaking load} = \frac{d_{SU}{}^3}{100R} \text{ kN}$$

where

d_{SU} is the basic stock diameter at quadrant or tiller given by Table 3.2.7 in Pt 3, Ch 3, in mm.

R = radius of quadrant, or length of tiller arm, in mm.

7.2.3 Steering leads are to be as direct as possible, and sharp bends are to be avoided. Sheaves are to be of adequate diameter and designed to prevent the steering leads from jumping or jamming.

7.2.4 Means are to be provided for adjusting the tension in the steering leads.

7.2.5 Where considered necessary, an efficient locking or brake arrangement is to be fitted to keep the rudder steady when a change from one type of steering to the other is required.

7.2.6 Where manually operated steering is permitted, *see* 7.1.2, the effort required to operate the tiller or steering wheel is to be not more than 160 N under normal conditions.

7.3 Control and monitoring

7.3.1 The alarms and safeguards for yachts and service craft less than 24 m are to be adequate for the type of steering system employed, *see* Table 1.7.1.

7.3.2 The requirements of 6.3.5 do not apply to service craft less than 24 m.

Table 1.7.1 Alarms

Item	Alarm	Note
Angular position of the Steering Mechanism	—	Indication
Steering power units, power	Failure	—
Steering motors	Overload, single phase	Also running indication on bridge
Control system power	Failure	—
Steering gear hydraulic oil level	Low	—
Auto pilot	Failure	Running indication
Hydraulic oil temperature	High	Where oil cooler is fitted

7.4 Electrical equipment

7.4.1 Consideration will be given to the electrical control equipment of simple steering systems on service craft less than 24 m or yachts, *see* Pt 16, Ch 2.

RULES AND REGULATIONS FOR THE CLASSIFICATION OF SPECIAL SERVICE CRAFT

PIPING SYSTEMS AND PRESSURE PLANT

JULY 2008

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PART 15

Lloyd's Register

■ *Section 1* Application

1.1 General

1.1.1 The requirements of this Chapter apply to the design and construction of piping systems including pipe fittings forming part of such systems.

■ *Section 2* Details to be submitted

2.1 Plans and information

2.1.1 At least three copies of the following plans and information are to be submitted.

2.1.2 Venting, sounding and drainage arrangements for all watertight compartments.

2.1.3 The following diagrammatic plans including details of the material and pipe dimensions/thickness:

- Bilge and ballast system including the capacities of the pumps on bilge service.
- Lubricating oil systems.
- Flammable liquids used for power transmission, control and heating systems.
- Cooling water systems for main and auxiliary services.
  Compressed air systems for main and auxiliary services.
  Steam systems with a design pressure above 7 bar.

2.1.4 Arrangement of oil fuel storage tanks with a capacity of over 0,5 m^3 where these do not form part of the structure of the craft.

2.1.5 Where it is intended to use plastic pipes for Class I, Class II and any Class III systems for which there are requirements in these Rules, details of the following:

(a) Properties of the materials.
(b) Operating conditions.
(c) Intended service and location.
(d) Pipes, fittings and joints.

2.1.6 Design details of the following components:

(a) Flexible hoses.
(b) Sounding devices.
(c) Resiliently seated valves.
(d) Expansion joints.
(e) Components of an unusual or novel nature.

2.1.7 The requirements for plans and information for the fire-fighting systems are given in Pt 17, Ch 1,1.2.3.

■ *Section 3* Class of pipes

3.1 General

3.1.1 Pipework systems are divided into three classes depending on the internal fluid and design temperature and pressure of the system.

3.1.2 Material test requirements for the different classes of pipe are detailed in the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.3 Acceptable jointing methods for the different classes of pipe are given in the appropriate Section of this Chapter. Material certificate requirements are given in Section 11.

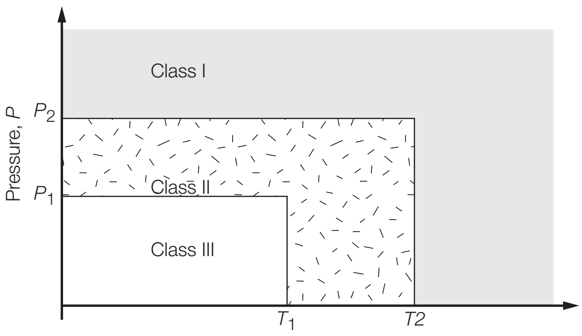
3.1.4 The maximum design pressure and temperature for Class II and III systems is given in Table 1.3.1. To illustrate, *see* Fig. 1.3.1.

3.1.5 Class I pipes are to be used where either the maximum design pressure or design temperature exceeds that applicable to Class II pipes.

Table 1.3.1 Maximum pressure and temperature conditions for Class II and III piping systems

Piping system	Class II		Class III	
	p	T	p	T
	bar	°C	bar	°C
Steam	16,0	300	7,0	170
Flammable liquids (*see* Note)	16,0	150	7,0	60
Other media	40,0	300	16,0	200

NOTE
Flammable liquids include: oil fuel, thermal oil and lubricating oil.



NOTE
T_1 and P_1 correspond to the maximum temperatures and pressures for a Class III piping system and T_2 and P_2 to those for a Class II piping system depending on the service.

Fig. 1.3.1 Classes of piping system

3.1.6 Class III pipes may also be used for open ended piping, e.g. overflows, vents, boiler waste steam pipes, open-ended drains, sounding pipes, etc.

■ *Section 4*
Design symbols and definitions

4.1 Design symbols

4.1.1 The symbols used in this Chapter are defined as follows:

a = percentage negative manufacturing tolerance on thickness
c = corrosion allowance, in mm
d = inside diameter of pipe, in mm, *see* 4.1.3
e = weld efficiency factor, *see* 4.1.4
p = design pressure, in bar, *see* 4.2
p_t = hydraulic test pressure, in bar
t = the minimum thickness of a straight pipe, in mm, including corrosion allowance and negative tolerance, where applicable
t_b = the minimum thickness of a straight pipe to be used for a pipe bend, in mm, including bending allowance, corrosion allowance and negative tolerance, where applicable
D = outside diameter of pipe, in mm, *see* 4.1.2
R = radius of curvature of a pipe bend at the centre line of the pipe, in mm
T = design temperature, in °C, *see* 4.3.1
σ = maximum permissible design stress, in N/mm^2

4.1.2 The outside diameter, D, is subject to manufacturing tolerances, but these are not to be used in the evaluation of formulae.

4.1.3 The inside diameter, d, is not to be confused with nominal pipe size, which is an accepted designation associated with outside diameters of standard rolling sizes.

4.1.4 The weld efficiency factor, e, is to be taken as 1 for seamless and electric resistance or induction welded steel pipes.

4.2 Design pressure

4.2.1 The design pressure, p, is the maximum permissible working pressure and is to be not less than the highest set pressure of the safety valve or relief valve. In systems which have no safety valve or relief valve, the design pressure is to to be taken as 1,1 times the maximum working pressure.

4.2.2 The design pressure of piping on the discharge from pumps is to be taken as the pump pressure at full rated speed against a shut valve. Where a safety valve or other protective device is fitted to restrict the pressure to a lower value than the shut valve load, the design pressure is to be the highest set pressure of the device.

4.2.3 For design pressure of steering system components and piping, *see* Part 14.

4.3 Design temperature

4.3.1 The design temperature is to be taken as the maximum temperature of the internal fluid, but in no case is it to be less than 50°C.

■ *Section 5*
Carbon and low alloy steels

5.1 General

5.1.1 The minimum thickness of steel pipes is to be determined by the formulae given in 5.1.2 and 5.1.3 except that in no case is it to be less than that shown in Table 1.5.1.

Table 1.5.1 Minimum thickness for steel pipes

External diameter D mm	Minimum pipe thickness mm
10,2–12	1,6
13,5–19	1,8
20–44,5	2,0
48,3–63,5	2,3
70–82,5	2,6
88,9–108	2,9
114,3–127	3,2
133–139,7	3,6
152,4–168,3	4,0
177,8 and over	4,5

NOTES
1. The thickness of air, overflow and sounding pipes for structural tanks is to be not less than 4,5 mm.
2. The thickness of bilge, ballast and general sea water pipes is to be not less than 4,0 mm.
3. The thickness of bilge, air, overflow and sounding pipes through ballast and oil fuel tanks, ballast lines through oil fuel tanks and oil fuel lines through ballast tanks is to be not less than 6,3 mm.
4. For air, bilge, ballast, oil fuel, overflow, sounding, and venting pipes as mentioned in Notes 1 to 3, where the pipes are efficiently protected against corrosion the thickness may be reduced by not more than 1 mm.
5. For air and sounding pipes the minimum thickness applies to the part of the pipe outside the tank but not exposed to weather. The section of pipe exposed to weather may be required to be suitably increased in thickness in accordance with statutory and loadline requirements as applicable.

5.1.2 The minimum thickness, t, of straight steel pressure pipes is to be determined by the following formula:

$$t = \left(\frac{pD}{20\sigma e + p} + c\right)\frac{100}{100 - a} \text{ mm}$$

where

symbols are as defined in 4.1.1
c is obtained from Table 1.5.2, *see also* 5.1.4
σ may be obtained directly from Table 1.5.3 or from the formula given in 5.1.6.

Table 1.5.2 Values of corrosion allowance (c) for steel pipes

Piping service	c, in mm
Saturated steam systems	0,8
Compressed air systems	1,0
Hydraulic oil systems	0,3
Lubricating oil systems	0,3
Fuel oil systems	1,0
Refrigerating plants	0,3
Fresh water systems	0,8
Sea-water systems in general	3,0

5.1.3 The minimum thickness, t_b, of a straight steel pipe to be used for a pipe bend is to be determined by the following formula, except where it can be demonstrated that the use of a thickness less than t_b would not reduce the thickness below t at any point after bending:

$$t_b = \left[\left(\frac{pD}{20\sigma e + p}\right)\left(1 + \frac{D}{2{,}5R}\right) + c\right]\frac{100}{100 - a} \text{ mm}$$

where

symbols are as defined in 4.1.1
c and σ are obtained as in 5.1.2
in general, R is to be not less than $3D$.

5.1.4 For pipes passing through tanks, where the thickness has been calculated in accordance with 5.1.2 or 5.1.3, an additional corrosion allowance is to be added to take account of external corrosion; the addition will depend on the external medium and the value is to be in accordance with Table 1.5.2.

5.1.5 Where the pipes are efficiently protected against corrosion, the corrosion allowance, c, may be reduced by not more than 50 per cent.

Table 1.5.3 Carbon and carbon-manganese steel pipes

Specified minimum tensile strength, N/mm^2	Maximum permissible design stress, N/mm^2												
	Maximum design temperature, °C												
	50	100	150	200	250	300	350	400	410	420	430	440	450
320	107	105	99	92	78	62	57	55	55	54	54	54	49
360	120	117	110	103	91	76	69	68	68	68	64	56	49
410	136	131	124	117	106	93	86	84	79	71	64	56	49
460	151	146	139	132	122	111	101	99	98	85	73	62	53
490	160	156	148	141	131	121	111	109	98	85	73	62	53

5.1.6 The maximum permissible design stress, σ, is to be taken as the lowest of the following values:

$$\sigma = \frac{E_t}{1,6}$$

$$\sigma = \frac{R_{20}}{2,7}$$

$$\sigma = \frac{S_R}{1,6}$$

where

E_t = specified minimum lower yield or 0,2 per cent proof stress at the design temperature

R_{20} = specified minimum tensile strength at ambient temperature

S_R = average stress to produce rupture in 100 000 hours at the design temperature

Values of E_t, R_{20} and S_R may be obtained from Chapter 6 of the Rules for Materials. Intermediate values may be obtained by interpolation.

5.1.7 Steel stub pipes between the shell plating and the sea valve are to be of short rigid construction, adequately supported and of substantial thickness.

5.2 Steel pipe joints

5.2.1 Joints in steel pipelines may be made by:

- Screwed on or welded on bolted flanges.
- Butt welds between pipes or between pipes and valve chests.
- Socket welded joints (up to 60,3 mm outside diameter).
- Threaded sleeve joints (parallel thread), *see also* 5.5.
- Special types of approved joints that have been shown to be suitable for the design conditions, *see also* 5.4.

5.2.2 Where pipes are joined by welding a suitable number of flanged joints are to be provided at suitable positions to facilitate installation and removal for maintenance.

5.2.3 Where welded pipes are protected against corrosion then the corrosion protection is to be applied after welding or the corrosion protection is to be made good in way of the weld damaged area.

5.2.4 Where it is not possible to make good the corrosion protection of the weld damaged area, then the pipe is to be considered to have no corrosion protection.

5.2.5 Where backing rings are used for welding pipes, then the effect of the flow obstruction of the backing ring and erosion/crevice corrosion of the backing ring is to be taken into account.

5.3 Welded-on flanges, butt welded joints and fabricated branch pieces

5.3.1 The dimensions and material of flanges and bolting, and the pressure-temperature rating of bolted flanges in pressure pipelines, in accordance with National or other established standards will be accepted.

5.3.2 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the pipes are intended.

5.3.3 Typical examples of welded-on flange attachments are shown in Fig. 1.5.1, and limiting design conditions for flange types (a) to (f) are shown in Table 1.5.4.

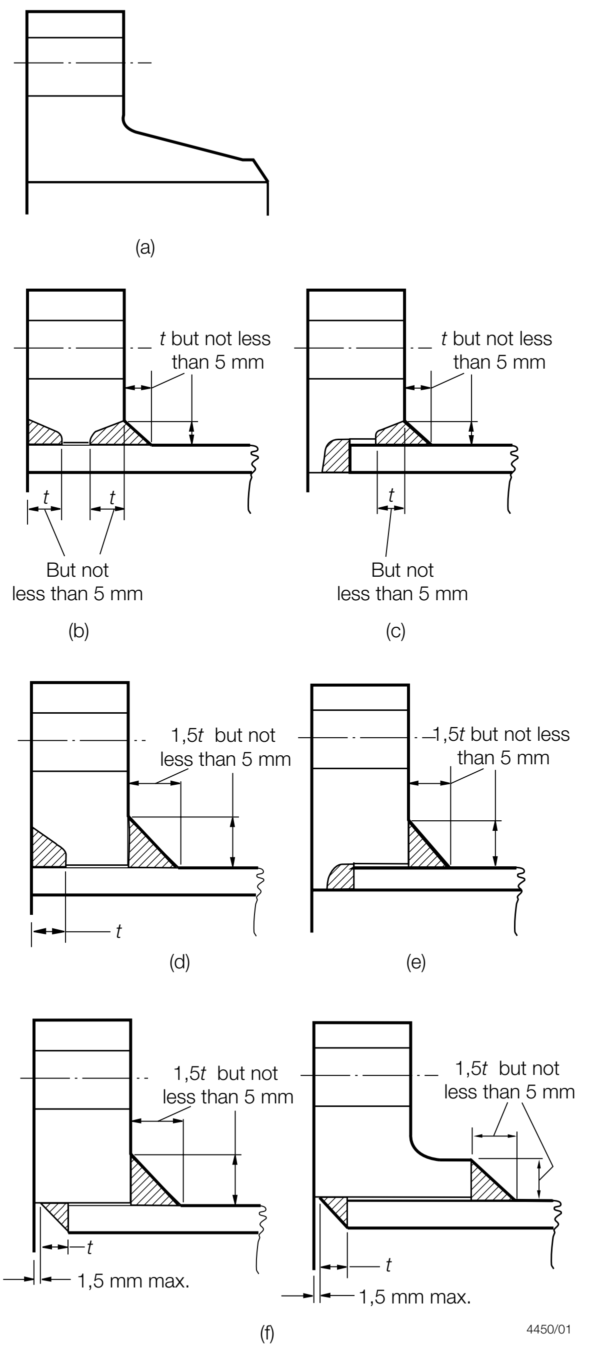


Fig. 1.5.1
Typical examples of welded flange connections

Table 1.5.4 Limiting design conditions for flange types

Flange type	Maximum pressure	Maximum temperature	Maximum pipe o.d.	Minimum pipe bore
		°C	mm	mm
(a)	Pressure-temperature ratings to be in accordance with a recognized standard	No restriction	No restriction	No restriction
(b)		No restriction	168,3 for alloy steels*	No restriction
(c)		No restriction	168,3 for alloy steels*	75
(d)		425	No restriction	No restriction
(e)		425	No restriction	75
(f)		425	No restriction	No restriction

* No restriction for carbon steels

5.3.4 Welded-on flanges are not to be a tight fit on the pipes. The maximum clearance between the bore of the flange and the outside diameter of the pipe is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

5.3.5 Where butt welds are employed in the attachment of flange type (a), in pipe-to-pipe joints or in the construction of branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided that the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to the thickness of the thinner at the butt joint. The welding necks of valve chests are to be sufficiently long to ensure that the valves are not distorted as the result of welding and subsequent heat treatment of the joints.

5.3.6 Where backing rings are used with flange type (a) they are to fit closely to the bore of the pipe and should be removed after welding. The rings are to be made of the same material as the pipes or of mild steel having a sulphur content not greater than 0,05 per cent.

5.3.7 Branches may be attached to pressure pipes by means of welding provided that the pipe is reinforced at the branch by a compensating plate or collar or other approved means, or alternatively that the thickness of pipe and branch are increased to maintain the strength of the pipe. These requirements also apply to fabricated branch pieces.

5.4 Screwed fittings

5.4.1 Screwed fittings including compression fittings may be used in piping systems not exceeding 41 mm outside diameter. Where the fittings are not in accordance with an acceptable standard then Lloyd's Register (hereinafter referred to as 'LR') may require the fittings to be subjected to special tests to demonstrate their suitability.

5.5 Threaded sleeve joints (parallel thread)

5.5.1 Threaded sleeve joints in accordance with National or other established standards may be used within the limits given in Table 1.5.5. They are not to be used in piping systems conveying flammable liquids.

Table 1.5.5 Limiting design conditions for threaded sleeve joints

Nominal bore	Maximum pressure	Maximum temperature
mm	bar (kgf/cm^2)	°C
≤ 25	12,0 (12,2)	260
> 25 ≤ 40	10,0 (10,2)	260
> 40 ≤ 80	8,5 (8,7)	260
> 80 ≤ 100	7,0 (7,1)	260

5.6 Socket weld joints

5.6.1 Socket weld joints may be used with carbon steel pipes not exceeding 60,3 mm outside diameter. Socket weld fittings are to be of forged steel and the material is to be compatible with the associated piping. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur. *See also* Ch 4,7.3.9.

5.6.2 The thickness of the socket weld fittings is to meet the requirements of 5.1.3 but is to be not less than 1,25 times the nominal thickness of the pipe or tube. The diametrical clearance between the outside diameter of the pipe and the bore of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided between the end of the pipe and the bottom of the socket.

5.6.3 The leg lengths of the fillet weld connecting the pipe to the socket weld fitting are to be such that the throat dimension of the weld is not less than the nominal thickness of the pipe or tube.

5.7 Welded sleeve joints

5.7.1 Welded sleeve joints may be used in Class III systems only, subject to the restrictions and general dimensional requirements given in 5.6 for socket weld joints.

5.7.2 The pipe ends are to be located in the centre of the sleeve with a 1,5 to 2,0 mm gap.

5.8 Other mechanical couplings

5.8.1 Pipe unions, compression couplings, or slip-on joints, as shown in Fig. 1.5.2, may be used if type approved for the service conditions and the intended application. The type approval is to be based on the results of testing of the actual joints. The acceptable use for each service is indicated in Table 1.5.6 and dependence upon the Class of piping, with limiting pipe dimensions, is indicated in Table 1.5.7.

5.8.2 Where the application of mechanical joints results in a reduction in pipe wall thickness due to the use of bite type rings or other structural elements, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.

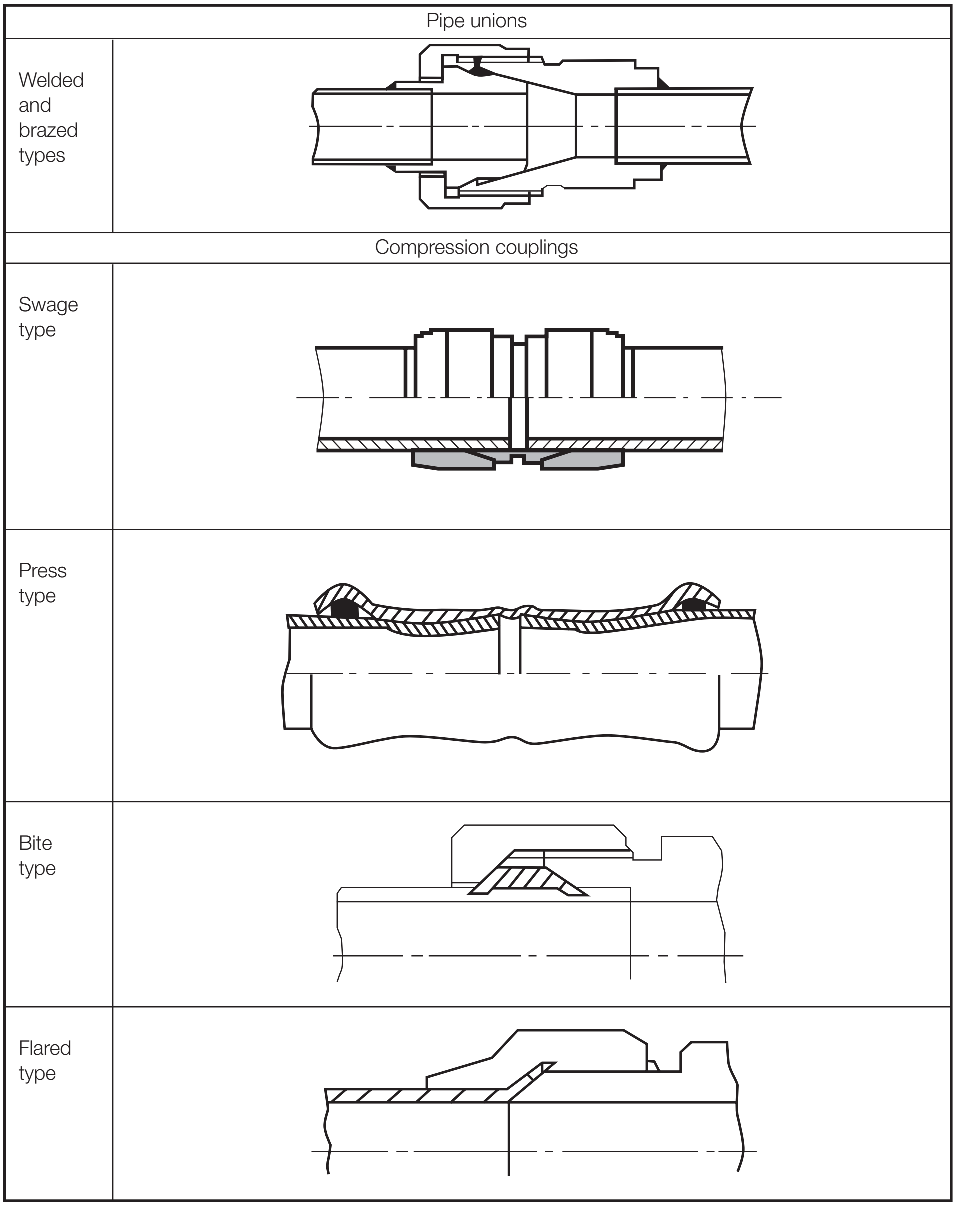


Fig. 1.5.2 Examples of mechanical joints (*see continuation*)

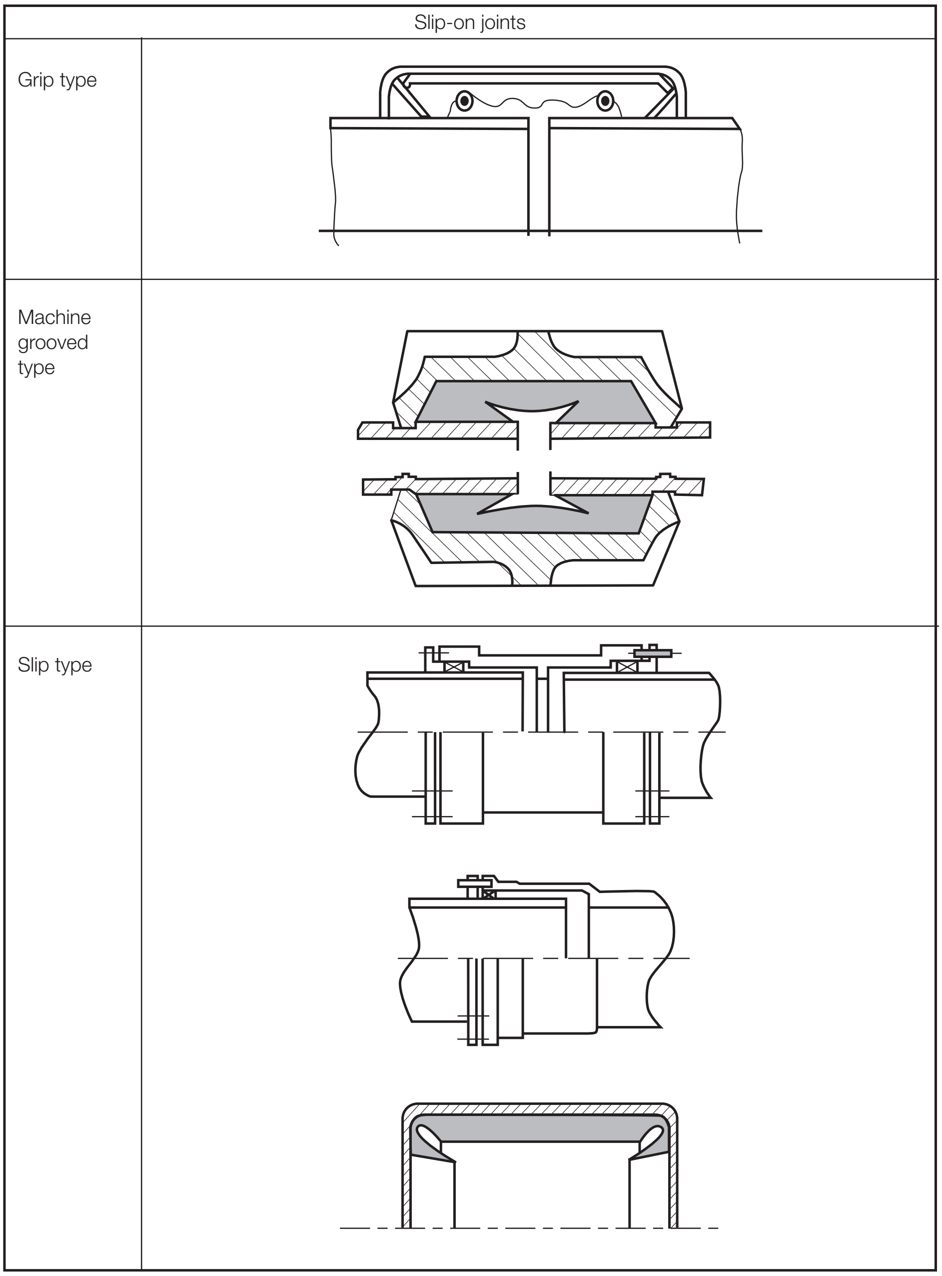


Fig. 1.5.2 Examples of mechanical joints (*conclusion*)

5.8.3 Construction of mechanical joints is to prevent the possibility of tightness failure affected by pressure pulsation, piping vibration, temperature variation and other similar adverse effects occurring during operation on board.

5.8.4 Materials of mechanical joints are to be compatible with the piping material and internal and external media.

5.8.5 Mechanical joints for pressure pipes are to be tested to a burst pressure of 4 times the design pressure. For design pressures above 200 bar the required burst pressure will be specially considered.

5.8.6 In general, mechanical joints are to be of fire-resistant type where required by Table 1.5.6.

5.8.7 Mechanical joints, which in the event of damage could cause fire or flooding, are not to be used in piping sections directly connected to the sea openings or tanks containing flammable fluids.

5.8.8 Mechanical joints are to be designed to withstand internal and external pressure as applicable and where used in suction lines are to be capable of operating under vacuum.

5.8.9 Generally, slip-on joints are not to be used in pipelines in cargo holds, tanks, and other spaces which are not easily accessible. Application of these joints inside tanks may only be accepted where the medium conveyed is the same as that in the tanks.

Table 1.5.6 Application of mechanical joints

Systems	Kind of connections		
	Pipe unions	Compression couplings (6)	Slip-on joints
Flammable fluids (Flash point <60°)			
Cargo oil lines	+	+	+5
Crude oil washing lines	+	+	+5
Vent lines	+	+	+3
Inert gas			
Water seal effluent lines	+	+	+
Scrubber effluent lines	+	+	+
Main lines	+	+	+2,5
Distribution lines	+	+	+5
Flammable fluids (Flash point > 60°)			
Cargo oil lines	+	+	+5
Fuel oil lines	+	+	+2,3
Lubricating oil lines	+	+	+2,3
Hydraulic oil	+	+	+2,3
Thermal oil	+	+	+2,3
Sea-water			
Bilge lines	+	+	+1
Fire main and water spray	+	+	+3
Foam system	+	+	+3
Sprinkler system	+	+	+3
Ballast system	+	+	+1
Cooling water system	+	+	+1
Tank cleaning services	+	+	+
Non-essential systems	+	+	+
Fresh water			
Cooling water system	+	+	+1
Condensate return	+	+	+1
Non-essential system	+	+	+
Sanitary/Drains/Scuppers			
Deck drains (internal)	+	+	+4
Sanitary drains	+	+	+
Scuppers and discharge (overboard)	+	+	—
Sounding/vent			
Water tanks/Dry spaces	+	+	+
Oil tanks (f.p.> 60°C)	+	+	+2,3
Miscellaneous			
Starting/Control air (1)	+	+	—
Service air (non-essential)	+	+	+
Brine	+	+	+
CO_2 system	+	+	—
Steam	+	+	—

KEY
+ Application is allowed
— Application is not allowed

NOTES
1. Inside machinery spaces of Category A – only approved fire resistant types.
2. Not inside machinery spaces of Category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions.
3. Approved fire resistant types.
4. Above freeboard deck only.
5. In pump rooms and open decks – only approved fire resistant types.
6. If compression couplings include any components which are sensitive to heat, they are to be of approved fire resistant type as required for slip-on joints.

Table 1.5.7 Application of mechanical joints depending on class of piping

Types of joints	Classes of piping systems		
	Class I	Class II	Class III
Pipe unions			
Welded and brazed type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Compression couplings			
Swage type	–	–	+
Bite type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Flared type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Press type	–	–	+
Slip-on joints			
Machine grooved type	+	+	+
Grip type	–	+	+
Slip type	–	+	+

KEY
\+ Application is allowed
– Application is not allowed

5.8.10 Unrestrained slip-on joints are only to be used in cases where compensation of lateral pipe deformation is necessary. Usage of these joints as the main means of pipe connection is not permitted.

■ *Section 6*
Copper and copper alloys

6.1 General

6.1.1 Copper and copper alloy pipes are acceptable for a wide range of services, including bilge pipework and where non heat-sensitive material is required.

6.1.2 The maximum permissible service temperature of copper and copper alloy pipes, valves and fittings is not to exceed 200°C for copper and aluminium brass, and 300°C for copper-nickel. Cast bronze valves and fittings complying with the requirements of Chapter 9 of the Rules for Materials may be accepted up to 260°C.

6.1.3 The minimum thickness, t, of straight copper and copper alloy pipes is to be determined by the following formula but is not to be less than that shown in Table 1.6.1:

$$t = \left(\frac{pD}{20\sigma + p} + c\right)\frac{100}{100 - a} \text{ mm}$$

where
symbols are as defined in 4.1.1
c = 0,8 mm for copper, aluminium brass, and copper-nickel alloys where the nickel content is less than 10 per cent
= 0,5 mm for copper-nickel alloys where the nickel content is 10 per cent or greater
= 0 where the media are non-corrosive relative to the pipe material

σ may be obtained from Table 1.6.2.
Intermediate values may be obtained by linear interpolation.

Table 1.6.1 Minimum thickness for copper and copper alloy pipes

Standard pipe sizes (outside diameter)	Minimum overriding nominal thickness	
	Copper	Copper alloy
8 to 10	1,0	0,8
12 to 20	1,2	1,0
25 to 44,5	1,5	1,2
50 to 76,1	2,0	1,5
88,9 to 108	2,5	2,0
133 to 159	3,0	2,5
193,7 to 267	3,5	3,0
273 to 457,2	4,0	3,5
508 and over	4,5	4,0

6.1.4 The minimum thickness t_b, of a straight seamless copper or copper alloy pipe to be used for a pipe bend is to be determined by the formula below, except where it can be demonstrated that the use of a thickness less than t_b would not reduce the thickness below t at any point after bending:

$$t_b = \left[\left(\frac{pD}{20\sigma + p}\right)\left(1 + \frac{D}{2,5R}\right) + c\right]\frac{100}{100 - a} \text{ mm}$$

where
symbols are as defined in 4.1.1
c and σ are obtained as in 6.1.3
in general, R is to be not less than $3D$.

6.1.5 Pipes are to be seamless, and branches are to be provided by cast or stamped fittings, pipe pressing or other approved fabrications.

Table 1.6.2 Copper and copper alloy pipes

Pipe material	Condition of supply	Specified minimum tensile strength, N/mm^2	Permissible stress, N/mm^2										
			Maximum design temperature, °C										
			50	75	100	125	150	175	200	225	250	275	300
Copper	Annealed	220	41,2	41,2	40,2	40,2	34,3	27,5	18,6	—	—	—	—
Aluminium brass	Annealed	320	78,5	78,5	78,5	78,5	78,5	51,0	24,5	—	—	—	—
90/19 Copper-nickel iron	Annealed	270	68,6	68,6	67,7	65,7	63,7	61,8	58,8	55,9	52,0	48,1	44,1
70/30 Copper-nickel	Annealed	360	81,4	79,4	77,5	75,5	73,5	71,6	69,6	67,7	65,7	63,7	61,8

6.1.6 Brazing and welding materials are to be suitable for the operating temperature and for the medium being carried.

6.1.7 Where silver brazing is used, strength is to be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet braze at the back of the flange or at the face is undesirable. The alloy used for silver brazing is to contain not less than 49 per cent silver.

6.1.8 The use of copper-zinc brazing alloy is not permitted.

6.2 Heat treatment

6.2.1 Pipes which have been hardened by cold bending are to be suitably heat treated on completion of manufacture and prior to being tested by hydraulic pressure. Copper pipes are to be annealed and copper alloy pipes are to be either annealed or stress relief heat treated.

■ *Section 7* **Cast iron**

7.1 General

7.1.1 Grey cast iron valves and fittings will, in general, be accepted in Class III piping systems except as stated in 7.1.5. Grey cast iron valves and fittings may be accepted in the Class II steam systems referred to in Table 1.3.1 but the design pressure or temperature is not to exceed 13 bar or 220°C, respectively.

7.1.2 Spheroidal or nodular graphite iron castings for valves and fittings in Class II and Class III piping systems are to be made in a grade having a specified minimum elongation not less than 12 per cent on a gauge length of $5{,}65\sqrt{S_o}$, where S_o is the actual cross-sectional area of the test piece.

7.1.3 Proposals for the use of this material in Class I piping systems will be specially considered, but in no case is the material to be used in systems where the design temperature exceeds 350°C.

7.1.4 Where the elongation is less than the minimum required by 7.1.2, the material is, in general, to be subject to the same limitations as grey cast iron.

7.1.5 Grey cast iron is not to be used for the following:

- Valves and fittings for boiler blow-down systems and other piping systems subject to shock or vibration.
- Shell valves and fittings, *see* Ch 2,3.1.
- Valves fitted on the collision bulkhead.

■ *Section 8* **Plastics**

8.1 General

8.1.1 Proposals to use plastics pipes will be considered in relation to the properties of the materials, the operating conditions and the intended service and location. Special consideration will be given to any proposed service for plastics pipes not mentioned in these Rules.

8.1.2 Attention is also to be given to *Guidelines for the Application of Plastics Pipes on Ships* contained in IMO Resolution A.753(18).

8.1.3 Plastics pipes and fittings will, in general, be accepted in Class III piping systems.

8.1.4 Plastics pipes are not acceptable for oil fuel, lubricating oil or other flammable liquid systems in machinery spaces, cargo holds and other spaces of high fire risk.

8.1.5 For Class I, Class II and any Class III piping systems for which there are Rule requirements, the pipes are to be of a type which has been approved by LR.

8.1.6 For domestic and similar services where there are no Rule requirements, the pipes need not be of a type which has been approved by LR. However, the fire safety aspects as referenced in 8.4, are to be taken into account.

8.1.7 The use of plastics pipes may be restricted by statutory requirements of the National Authority of the country in which the craft is to be registered.

8.2 Design and performance criteria

8.2.1 Pipes and fittings are to be of robust construction and are to comply with a national or other established standard, consistent with the intended use. Particulars of pipes, fittings and joints are to be submitted for consideration.

8.2.2 The design and performance criteria of all piping systems, independent of service or location, are to meet the requirements of 8.3.

8.2.3 Depending on the service and location, the fire safety aspects such as fire endurance, and fire protection coatings, are to meet the requirements of 8.4.

8.2.4 Plastics piping is to be electrically conductive when:
(a) Carrying fluids capable of generating electrostatic charges.
(b) Passing through dangerous zones and spaces, regardless of the fluid being conveyed.

Suitable precautions against the build up of electrostatic charges are to be provided in accordance with the requirements of 8.5, *see also* Pt 16, Ch 2,1.12.

8.3 Design strength

8.3.1 The strength of pipes is to be determined by hydrostatic pressure tests to failure on representative sizes of pipe. The strength of fittings is to be not less than the strength of the pipes.

8.3.2 In service, the pipe is not to be subjected to a pressure greater than the nominal internal pressure pN_i.

8.3.3 The nominal internal pressure, pN_i, of the pipe is to be determined by the lesser of the following:

$$pN_i \leq \frac{P_{st}}{4}$$

$$pN_i \leq \frac{P_{lt}}{2,5}$$

where

p_{st} = short term hydrostatic test failure pressure, in bar

p_{lt} = long term hydrostatic test failure pressure (100 000 hours), in bar.

Due to the length of time stipulated for the long term test, testing may be carried out over a reduced period of time and the results extrapolated using a suitable standard such as ASTM D2837 and ASTM D1598.

8.3.4 The nominal external pressure, pN_e of the pipe, defined as the maximum total of internal vacuum and external static pressure head to which the pipe may be subjected, is to be determined by the following:

$$pN_e \leq \frac{P_{col}}{3}$$

where

p_{col} = pipe collapse pressure in bar

The pipe collapse pressure is to be not less than 3 bar.

8.3.5 Piping is to meet the design requirements of 8.3.2 and 8.3.4 over the range of service temperature it will experience.

8.3.6 High temperature limits and pressure reductions relative to nominal pressures are to be in accordance with a recognised standard, but in each case the maximum working temperature is to be at least 20°C lower than the minimum temperature of deflection under load of the resin or plastics material without reinforcement. The minimum temperature of deflection under load is not to be less than 80°C, *see also* Ch 14,4 of the Rules for Materials.

8.3.7 Where it is proposed to use plastics piping in low temperature services, design strength testing is to be made at a temperature 10°C lower than the minimum working temperature.

8.3.8 For guidance, typical temperature and pressure limits are indicated in Tables 1.8.1 and 1.8.2. The Tables are related to water service only.

8.3.9 The selection of plastics materials for piping is to take account of other factors such as impact resistance, ageing, fatigue, erosion resistance, fluid absorption and material compatibility such that the design strength of the piping is not reduced below that required by these Rules.

8.3.10 Design strength values may be verified experimentally or by a combination of testing and calculation methods.

8.4 Fire performance criteria

8.4.1 Where plastics pipes are used in systems essential for the safe operation of the craft, or for containing combustible fluids or sea-water where leakage or failure could result in fire or in the flooding of watertight compartments, the pipes and fittings are to be of a type which have been fire endurance tested, *see also* 8.2.3.

8.4.2 Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance standards required, the coating is to be resistant to products likely to come into contact with the piping and be suitable for the intended application.

8.5 Electrical conductivity

8.5.1 Where a piping system is required to be electrically conductive for the control of static electricity, the resistance per unit length of the pipe, bends, elbows, fabricated branch pieces, etc., is not to exceed 0,1 MΩ/m, *see also* 8.2.4.

Table 1.8.1 Typical temperature and pressure limits for thermoplastic pipes

Material	Nominal pressure, bar	Maximum permissible working pressure, bar						
		–20°C to 0°C	30°C	40°C	50°C	60°C	70°C	80°C
PVC	10		7,5	6				
	16		12	9	6			
ABS	10	7,5	7,5	7	6			
	16	12	12	10,5	9	7,5	6	
HDPE	10	7,5	6					
	16	12	9,5	6				

Abbreviations:

PVC Polyvinyl chloride
ABS Acrylonitrile – butadiene – styrene
HDPE High density polyethylene

Table 1.8.2 Typical temperature and pressure limits for glass fibre reinforced epoxy (GRE) and glass fibre reinforced polyester (GRP) pipes

Min. temperature of deflection under load of resin	Nominal pressure, bar	Maximum permissible working pressure, bar							
		–50°C to 30°C	40°C	50°C	60°C	70°C	80°C	90°C	95°C
80°C	10	10	9	7,5	6				
	16	16	14	12	9,5				
	25	16	16	16	15				
100°C	10	10	10	9,5	8,5	7	6		
	16	16	16	15	13,5	11	9,5		
	25	16	16	16	16	16	15		
135°C	10	10	10	10	10	9,5	8,5	7	6
	16	16	16	16	16	15	13,5	11	9,5
	25	16	16	16	16	16	16	16	15

8.6 Installation and construction

8.6.1 All pipes are to be adequately but freely supported. Suitable provision is to be made for expansion and contraction to take place without unduly straining the pipes.

8.6.2 Pipes may be joined by mechanical couplings or by bonding methods such as welding, laminating, adhesive bonding or other approved means.

8.6.3 Sufficient mechanical joints are to be provided to enable the pipes to be readily removed.

8.6.4 The required fire endurance level of the pipe is to be maintained in way of pipe supports, joints and fittings, including those between plastics and metallic pipes.

8.6.5 Where piping systems are arranged to pass through watertight bulkheads or decks, provision is to be made for maintaining the integrity of the bulkhead or deck by means of metallic bulkhead pieces. The bulkhead pieces are to be protected against corrosion and so constructed to be of a strength equivalent to the intact bulkhead; attention is drawn to 8.6.1. Details of the arrangements are to be submitted for approval.

8.6.6 Where a piping system is required to be electrically conductive, for the control of static electricity, continuity is to be maintained across the joints and fittings, and the system is to be earthed, *see also* Pt 16, Ch 2,1.12.

8.7 Testing

8.7.1 The hydraulic testing of pipes and fittings is to be in accordance with Section 14.

8.7.2 Where a piping system is required to be electrically conductive, tests are to be carried out to verify that the resistance to earth from any point in the system does not exceed 1 MΩ.

Section 9
Stainless steel

9.1 General

9.1.1 Stainless steels may be used for a wide range of services and are particularly suitable for use at elevated temperatures. For guidance on the use of austenitic steels in sea water systems, *see* 16.3.4.

9.1.2 The minimum thickness of stainless steel pipes is to be determined from the formula given in 5.1.2 or 5.1.3 using a corrosion allowance of 0,8 mm. Values of the 0,2 per cent proof stress and tensile strength of the material for use in the formula in 5.1.6 may be obtained from Table 6.5.2 in Chapter 6 of the Rules for Materials.

9.1.3 Where stainless steel is used in lubricating oil and hydraulic oil systems, the corrosion allowance may be reduced to 0,3 mm.

9.1.4 In no case is the thickness of stainless steel pipes to be less than that shown in Table 1.9.1.

Table 1.9.1 Minimum thickness for stainless steel pipes

Standard pipe sizes (outside diameter)			Minimum nominal thickness
mm		mm	mm
8,0	to	10,0	0,8
12,0	to	20,0	1,0
25,0	to	44,5	1,2
50,0	to	76,1	1,5
88,9	to	108,0	2,0
133,0	to	159,0	2,5
193,7	to	267,0	3,0
273,0	to	457,2	3,5

9.1.5 Joints in stainless steel pipework may be made by any of the techniques described in 5.2 to 5.7.

9.1.6 Where pipework is butt welded, this should preferably be accomplished without the use of backing rings, in order to eliminate the possibility of crevice corrosion between the backing ring and pipe.

Section 10
Aluminium alloy

10.1 General

10.1.1 The use of aluminium alloy material in Class III piping systems will be considered in relation to the fluid being conveyed and operating conditions of temperature and pressure.

10.1.2 In general, aluminium alloy may be used for air and sounding pipes for water tanks and dry spaces providing it can be shown that pipe failure will not cause a loss of integrity across watertight divisions. In craft of aluminium construction, aluminium alloy may also be used for air and sounding pipes for oil fuel, lubricating oil and other flammable liquid tanks provided the pipes are suitably protected against the effects of fire.

10.1.3 Aluminium alloy pipes are not to be used in machinery spaces or cargo holds for conveying oil fuel, lubricating oil or other flammable liquids, or for bilge suction pipework within machinery spaces.

10.1.4 Aluminium alloy pipes are not acceptable for fire extinguishing pipes unless they are suitably protected against the effect of heat. The use of aluminium alloy with appropriate insulation will be considered when it has been demonstrated that the arrangements provide equivalent structural and integrity properties compared to steel. In open and exposed locations, where the insulation material is likely to suffer from mechanical damage, suitable protection is to be provided.

10.1.5 The minimum thickness of aluminium alloy pipes is to be not less than that shown in Table 1.10.1.

Table 1.10.1 Minimum thickness of aluminium pipes

Nominal pipe size (mm)	Minimum wall thickness (mm)
10	1,7
15	2,1
20	2,1
25	2,8
40	2,8
50	2,8
80	3,0
100	3,0
150	3,4
200	3,8
250 and over	4,2

10.1.6 Design requirements for aluminium pressure pipes for design pressures greater than 7 bar will be specially considered.

10.1.7 Attention is drawn to the susceptibility of aluminium to corrosion in the region of welded connections.

Section 11
Material certificates

11.1 Metallic materials

11.1.1 Materials for Class I and II piping systems and components as defined in Table 1.3.1, also for shell valves and fittings and fittings on the collision bulkhead are to be manufactured and tested in accordance with the Rules for Materials.

11.1.2 Ferrous castings and forgings for Class I and II piping systems are to be produced at a works approved by LR.

11.1.3 Materials for Class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable National Standards.

11.1.4 The Manufacturer's materials test certificate will be accepted for all classes of piping and components in lieu of an LR materials certificate where the maximum design conditions are less than shown in Table 1.11.1.

Table 1.11.1 Maximum conditions for pipes, valves and fittings for which Manufacturer's materials test certificate is acceptable

Material	Working temperature °C	DN = Nominal Diameter, mm P_W = Working Pressure, bar
Carbon and low alloy steel. Stainless steel. Spheroidal or nodular cast iron.	< 300	DN < 50 or P_W x DN < 2500
Copper alloy	< 200	DN < 50 or P_W x DN < 1500

11.2 Non-metallic materials

11.2.1 Pipes and fittings intended for applications in Class I, Class II and Class III systems for which there are Rule requirements are to be manufactured in accordance with Chapter 14 of the Rules for Materials.

■ *Section 12*
Requirements for valves

12.1 General

12.1.1 The design, construction and operational capability of valves are to be in accordance with an acceptable National or International Standard appropriate for the piping system. Where valves are not in accordance with an acceptable Standard, details are to be submitted for consideration.

12.1.2 Valves are to be made of steel, cast iron, copper alloy, or other approved material suitable for the intended purpose.

12.1.3 Valves having isolation or sealing components sensitive to heat are not to be used in spaces where leakage or failure caused by fire could result in fire spread, flooding or the loss of an essential service.

12.1.4 Where valves are required to be capable of being closed remotely in the event of fire, the valves, including their control gear, are to be of steel construction or of an acceptable fire tested design.

12.1.5 Valves are to be arranged for clockwise closing and are to be provided with indicators showing whether they are open or shut unless this is readily obvious.

12.1.6 Valves are to be so constructed as to prevent the possibility of valve covers or glands being slackened back or loosened when the valves are operated.

12.1.7 Valves and cocks are to be fitted with legible nameplates, and, unless otherwise specifically mentioned in the Rules, the valves and cocks are to be fitted in places where they are at all times readily accessible.

12.1.8 Valves are to be used within their specified pressure and temperature rating for all normal operating conditions, and are to be suitable for the intended purpose.

12.1.9 Valves intended for submerged installation are to be suitable for both internal and external media. Spindle sealing is to prevent ingress of external media at the maximum external pressure head expected in service.

12.1.10 Additional requirements for shell valves are given in Ch 2,3.

12.2 Valves with remote control

12.2.1 All valves which are provided with remote control are to be arranged for local manual operation, independent of the remote operating mechanism.

12.2.2 In the case of valves which are required by the Rules to be provided with remote control, opening and/or closing of the valves by local manual means is not to render the remote control system inoperable.

12.3 Resiliently seated valves

12.3.1 Valves, having isolation or sealing components sensitive to heat, are not to be used in spaces where leakage or failure caused by fire could result in fire spread, flooding or loss of an essential service.

12.3.2 Where the valves are of the diaphragm type, they are not acceptable as shut off valves at the shell plating.

12.3.3 Resiliently seated valves are not to be used in main or auxiliary machinery spaces as branch or direct bilge suction valves or as pump suction valves from the main bilge line (except where the valve is located in the immediate vicinity of the pump and in series with a metal seated non-return valve. The non-return valve is to be fitted on the bilge main side of the resiliently seated valve). Where they are used in other locations and within auxiliary machinery spaces having little or no fire risk they should be of an approved fire safe type and used in conjunction with a metal seated non-return valve.

12.3.4 Resiliently seated valves are not acceptable for use in fire water mains unless they have been satisfactorily fire tested.

■ *Section 13*
Requirements for flexible hoses

13.1 General

13.1.1 A flexible hose assembly is a short length of metallic or non-metallic hose normally with prefabricated end fittings ready for installation.

13.1.2 For the purpose of approval for the applications in 13.2, details of the materials and construction of the hoses, and the method of attaching the end fittings together with evidence of satisfactory prototype testing, are to be submitted for consideration.

13.1.3 The use of hose clamps and similar types of end attachments are not be used for flexible hoses in piping systems for steam, flammable media, starting air systems or for sea water systems where failure may result in flooding. In other piping systems, the use of hose clamps may be accepted where the working pressure is less than 5 bar and provided that there are two clamps at each end connection.

13.1.4 Flexible hoses are to be limited to a length necessary to provide for relative movement between fixed and flexibly mounted items of machinery/equipment or systems.

13.1.5 Flexible hoses are not to be used to compensate for misalignment between sections of piping.

13.1.6 Flexible hose assemblies are not to be installed where they may be subjected to torsional deformation (twisting) under normal operating conditions.

13.1.7 The number of flexible hoses in piping systems mentioned in this Section is to be kept to a minimum and to be limited for the purpose stated in 13.2.1.

13.1.8 Where flexible hoses are intended for conveying flammable fluids in piping systems that are in close proximity to hot surfaces, electrical installation or other sources of ignition, the risk of ignition due to failure of the hose assembly and subsequent release of fluids is to be mitigated as far as practicable by the use of screens or other suitable protection.

13.1.9 Flexible hoses are to be installed in clearly visible and readily accessible locations.

13.1.10 The installation of flexible hose assemblies is to be in accordance with the manufacturer's instructions and use limitations with particular attention to the following:
(a) Orientation.
(b) End connection support (where necessary).
(c) Avoidance of hose contact that could cause rubbing and abrasion.
(d) Minimum bend radii.

13.1.11 Flexible hoses are to be permanently marked by the manufacturer with the following details:
(a) Hose manufacturer's name or trademark.
(b) Date of manufacture (month/year).
(c) Designation type reference.
(d) Nominal diameter.
(e) Pressure rating.
(f) Temperature rating.
Where a flexible hose assembly is made up of items from different manufacturers, the components are to be clearly identified and traceable to evidence of prototype testing.

13.2 Applications for rubber hoses

13.2.1 Short joining lengths of flexible hoses complying with the requirements of this Section may be used, where necessary, to accommodate relative movement between various items of machinery connected to permanent piping systems. The requirements of this Section may also be applied to temporarily-connected flexible hoses or hoses of portable equipment.

13.2.2 Rubber or plastics hoses, with integral cotton or similar braid reinforcement, may be used in fresh and sea-water cooling systems. In the case of sea-water systems, where failure of the hoses could give rise to the danger of flooding, the hoses are to be suitably enclosed.

13.2.3 Rubber or plastics hoses, with single or double closely woven integral wire braid or other suitable material reinforcement, or convoluted metal pipes with wire braid protection, may be used in bilge, ballast, compressed air, fresh water, sea-water, oil fuel, lubricating oil, Class III steam, hydraulic and thermal oil systems. Where rubber or plastics hoses are used for oil fuel supply to burners, the hoses are to have external wire braid protection in addition to the integral wire braid. Flexible hoses for use in steam systems are to be of metallic construction.

13.2.4 Flexible hoses are not to be used in high pressure fuel oil injection systems.

13.2.5 The requirements in this Section for flexible hose assemblies are not applicable to hoses intended to be used in fixed fire extinguishing systems.

13.3 Design requirements

13.3.1 Flexible hose assemblies are to be designed and constructed in accordance with recognised National or International Standards acceptable to LR.

13.3.2 Flexible hoses are to be complete with approved end fittings in accordance with manufacturer's specification. End connections which do not have flanges are to comply with 5.8 as applicable and each type of hose/fitting combination is to be subject to prototype testing to the same standard as that required by the hose with particular reference to pressure and impulse tests.

13.3.3 Flexible hose assemblies intended for installation in piping systems where pressure pulses and/or high levels of vibration are expected to occur in service, are to be designed for the maximum expected impulse peak pressure and forces due to vibration. The tests required by 13.4 are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

13.3.4 Flexible hose assemblies constructed of non-metallic materials intended for installation in piping systems for flammable media, and sea-water systems where failure may result in flooding, are to be of fire-resistant type. Fire resistance is to be demonstrated by testing to ISO 15540 and ISO 15541.

13.3.5 Flexible hose assemblies are to be suitable for the intended location and application, taking into consideration ambient conditions, compatibility with fluids under working pressure and temperature conditions consistent with the manufacturer's instructions and any other applicable requirements in the Rules.

13.4 Testing

13.4.1 Acceptance of flexible hose assemblies is subject to satisfactory prototype testing. Prototype test programmes for flexible hose assemblies are to be submitted by the manufacturer and are to be sufficiently detailed to demonstrate performance in accordance with the specified standards.

13.4.2 For a particular hose type complete with end fittings, the tests, as applicable, are to be carried out on different nominal diameters for pressure, burst, impulse and fire resistance in accordance with the requirements of the relevant standard. The following standards are to be used as applicable:

- ISO 6802 – Rubber and plastics hoses and hose assemblies – Hydraulic pressure impulse test without flexing.
- ISO 6803 – Rubber and plastics hoses and hose assemblies – Hydraulic pressure impulse test with flexing.
- ISO 15540 – Ships and marine technology – Fire resistance of hose assemblies – Test methods.
- ISO 15541 – Ships and marine technology – Fire resistance of hose assemblies – Requirements for test bench.
- ISO 10380 – Pipework – Corrugated metal hoses and hose assemblies.

Other standards may be accepted where agreed by LR.

13.4.3 All flexible hose assemblies are to be satisfactorily prototype burst tested to an international standard (*see* Note) to demonstrate they are able to withstand a pressure of not less than four times the design pressure without indication of failure or leakage.

NOTE:
The International Standards, e.g. EN or SAE for burst testing of non-metallic hoses, require the pressure to be increased until burst without any holding period at 4 x Maximum Working Pressure.

Section 14
Hydraulic tests on pipes and fittings

14.1 Hydraulic tests before installation on board

14.1.1 All Class I and II pipes and their associated fittings are to be tested by hydraulic pressure. Further, all steam, feed, compressed air and oil fuel pipes, together with their fittings, are to be similarly tested where the design pressure is greater than 7 bar. The test is to be carried out after completion of manufacture and before installation on board and, where applicable, before insulating and coating.

14.1.2 The test pressure is to be 1,5 times the design pressure, as defined in 4.2.

14.1.3 Shell valves and valves on the collision bulkhead are to be tested by hydraulic pressure to 1,5 times the nominal pressure rating of the valve at ambient temperature.

14.2 Testing after assembly on board

14.2.1 Oil fuel piping is to be tested by hydraulic pressure, after installation on board, to 1,5 times the design pressure but in no case to less than 3,5 bar.

14.2.2 Where pipes specified in 14.1.1 are butt welded together during assembly on board, they are to be tested by hydraulic pressure in accordance with the requirements of 14.2.1 after welding. The pipe lengths may be insulated, except in way of the joints made during installation and before the hydraulic test is carried out.

14.2.3 The hydraulic test required by 14.2.2 may be omitted provided non–destructive tests by ultrasonic or radiographic methods are carried out on the entire circumference of all butt welds with satisfactory results.

14.2.4 Where ultrasonic tests have been carried out, the manufacturer is to provide the Surveyor with a signed statement confirming that ultrasonic examination has been carried out by an approved operator and that there were no indications of defects which could be expected to have prejudicial effect on the service performance of the piping.

CROSS-REFERENCE

See also Ch 2,2.4 for testing after installation.

Section 15 Requirements for small craft which are not required to comply with the HSC Code

15.1 General

15.1.1 The requirements of Sections 1 to 13 apply, except where modified by this Section.

15.2 Details to be submitted

15.2.1 Details of oil fuel storage tanks over 0,25 m^3, where these do not form part of the structure of the craft, are to be submitted.

15.2.2 Design details of the components listed in 2.1.6 are not required.

15.3 Materials

15.3.1 Materials for which no provision is made in this Chapter may be accepted provided that they comply with an acceptable National or International Standard and are satisfactorily tested as may be considered necessary. Manufacturer's material test certificates are not required unless the material is of unusual or special specification.

15.3.2 Shell valves and cocks, inlet chests, distance pieces and other sea connections are to be of approved ductile material. Due attention is to be paid to the compatibility of the material with that of the shell. Ordinary grey cast iron is not acceptable.

15.4 Aluminium alloy

15.4.1 Proposals for the use of aluminium alloy pipes in bilge systems in machinery spaces will be considered, provided that a single failure in any section of the pipe does not render the whole system inoperable.

15.4.2 Aluminium alloy pipes may be used for fire-fighting systems outside machinery spaces in locations of low fire risk.

15.5 Plastics pipes

15.5.1 IMO Resolution A.753(18) *Guidelines for the Application of Plastics Pipes on Ships* does not apply.

15.5.2 The requirements of 8.1.5 do not apply but where plastics pipes are used for bilge and cooling water services they are to be of a type which has been approved by LR. However, fire endurance testing is not required.

15.5.3 Where plastics pipes are used in bilge systems in machinery spaces, a single failure in any section of the pipe is not to render the whole system inoperable.

15.6 Copper and copper alloys

15.6.1 Where copper and copper alloy pipes are in accordance with an acceptable National Standard/ Specification which is applicable to the intended service or media, Table 1.6.1 need not be applied.

Section 16 Guidance notes on metal pipes for water services

16.1 General

16.1.1 These guidance notes, except where it is specifically stated, apply to sea-water piping systems.

16.1.2 In addition to the selection of suitable materials, careful attention should be given to the design details of the piping system and the workmanship in fabrication, construction and installation of the pipework in order to obtain maximum life in service.

16.2 Materials

16.2.1 Materials used in sea water piping systems include:
- Galvanized steel.
- Stainless and duplex steel, *see also* 16.3.4.
- Steel pipes lined with rubber, plastics or stoved coatings.
- Copper.
- 90/10 copper-nickel-iron.
- 70/30 copper-nickel.
- Aluminium alloy.
- Aluminium brass.
- Bronze.
- Approved plastics.

16.2.2 Selection of materials should be based on:
- The ability to resist general and localised corrosion, such as pitting, impingement attack and cavitation throughout all the flow velocities likely to be encountered;
- Compatibility with the other materials in the system, such as valve bodies and casings, in order to minimize bimetallic corrosion;
- The ability to resist selective corrosion, e.g. dezincification of brass, dealuminification of aluminium brass and graphitization of cast iron;
- The ability to resist stress corrosion and corrosion fatigue, and;
- The amenability to fabrication by normal practices.

16.3 Steel pipes

16.3.1 Steel pipes should be protected against corrosion and protective coatings should be applied on completion of all fabrication, i.e. bending, forming and welding of the steel pipes.

16.3.2 Welds should be free from lack of fusion and crevices. The surfaces should be dressed to remove slag and spatter and this should be done before coating. The coating should be continuous around the ends of the pipes and on the faces of flanges.

16.3.3 Galvanizing the bores and flanges of steel pipes as protection against corrosion is common practice, and is recommended as the minimum protection for pipes in sea-water systems, including those for bilge and ballast service.

16.3.4 Austenitic stainless steel pipes are not recommended for salt water services in polluted waters or where stagnant conditions exist. Steel of specification 316L or better may give satisfactory service in water circulating systems for clean sea water.

16.3.5 Rubber lined pipes are effective against corrosion and suitable for higher water velocities. The rubber lining should be free from defects, e.g. discontinuities, pinholes, etc., and it is essential that the bonding of the rubber to the bore of the pipe and flange face is sound. Rubber linings should be applied by firms specializing in this form of protection.

16.3.6 The foregoing comments on rubber lined pipes also apply to pipes lined with plastics.

16.3.7 Stove coating of pipes as protection against corrosion should only be used where the pipes will be efficiently protected against mechanical damage.

16.4 Copper and copper alloy pipes

16.4.1 Copper pipes are particularly susceptible to perforation by corrosion/erosion and should only be used for low water velocities and where there is no excessive local turbulence.

16.4.2 Aluminium brass and copper-nickel-iron alloy pipes give good service in reasonably clean sea-water. For service with polluted river or harbour waters, copper-nickel-iron alloy pipes with at least 10 per cent nickel are preferable. Alpha-brasses, i.e. those containing 70 per cent or more copper, must be inhibited effectively against dezincification by suitable additions to the composition. Alpha beta-brasses, i.e. those containing less than 70 per cent copper, should not be used for pipes and fittings.

16.4.3 New copper alloy pipes should not be exposed initially to polluted water. Clean sea-water should be used at first to allow the metals to develop protective films. If this is not available the system should be filled with inhibited town mains water.

16.5 Flanges

16.5.1 Where pipes are exposed to sea-water on both external and internal surfaces, flanges should be made, preferably, of the same material. Where sea-water is confined to the bores of pipes, flanges may be of the same material or of less noble metal than that of the pipe.

16.5.2 Fixed or loose type flanges may be used. The fixed flanges should be attached to the pipes by fillet welds or by capillary silver brazing. Where welding is used, the fillet weld at the back should be a strength weld and that in the face, a seal weld.

16.5.3 Inert gas shielded arc welding is the preferred process but metal arc welding may be used on copper-nickel-iron alloy pipes.

16.5.4 Mild steel flanges may be attached by argon arc welding to copper-nickel-iron pipes and give satisfactory service, provided that no part of the steel is exposed to the sea-water.

16.5.5 Where silver brazing is used, strength should be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet braze at the back of the flange or at the face is undesirable. The alloy used for silver brazing should contain not less than 49 per cent silver.

16.5.6 The use of a copper-zinc brazing alloy is not permitted.

16.6 Water velocity

16.6.1 Water velocities should be carefully assessed at the design stage and the materials of pipes, valves, etc., selected to suit the conditions.

16.6.2 The water velocity in copper pipes should not exceed 1 m/s.

16.6.3 The water velocity in the pipes of the materials below should normally be not less than about 1 m/s in order to avoid fouling and subsequent pitting, but should not be greater than the following:

Galvanized steel	3,0 m/s
Aluminium brass	3,0 m/s
90/10 copper-nickel-iron	3,5 m/s
70/30 copper-nickel	5,0 m/s.

16.7 Fabrication and installation

16.7.1 Attention should be given to ensuring streamlined flow and reducing entrained air in the system to a minimum. Abrupt changes in the direction of flow, protrusions in the bores of pipes and other restrictions of flow should be avoided. Branches in continuous flow lines should be set at a shallow angle to the main pipe, and the junction should be smooth.

16.7.2 Pipe bores should be smooth and clean.

16.7.3 Jointing should be flush with the bore surfaces of pipes and misalignment of adjacent flange faces should be reduced to a minimum.

16.7.4 Pipe bends should be of as large a radius as possible, and the bore surfaces should be smooth and free from puckering at these positions. Any carbonaceous films or deposits formed on the bore surfaces during the bending processes should be carefully removed. Organic substances are not recommended for the filling of pipes for bending purposes.

16.7.5 The position of supports should be given special consideration in order to minimize vibration and ensure that excessive bending moments are not imposed on the pipes.

16.7.6 Systems should not be left idle for long periods, especially where the water is polluted.

16.7.7 Strainers should be provided at the inlet to sea-water systems.

16.8 Metal pipes for fresh water services

16.8.1 Mild steel or copper pipes are normally satisfactory for service in fresh water applications. Hot fresh water, however, may promote corrosion in mild steel pipes unless the hardness and pH of the water are controlled.

16.8.2 Water with a slight salt content should not be left stagnant for long periods in mild steel pipes. Low salinity and the limited supply of oxygen in such conditions promote the formation of black iron oxide, and this may give rise to severe pitting. Where stagnant conditions are unavoidable, steel pipes should be galvanized, or pipes of suitable non-ferrous material used.

16.8.3 Copper alloy pipes should be treated to remove any carbonaceous films or deposits before the tubes are put into service.

16.8.4 Brass fittings and flanges in contact with water should be made of an alpha-brass effectively inhibited against dezincification by suitable additions to the composition.

16.8.5 Aluminium brass has been widely used as material for heat exchanger and condenser tubes, but its use in 'once through' systems is not recommended since, under certain conditions, it is prone to pitting and cracking.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of Sections 1 to 11 of this Chapter apply to all craft which are required to satisfy the relevant design and construction regulations of the HSC Code.

1.1.2 Special requirements for multi-hull craft are given in Section 12.

1.1.3 Additional requirements for Passenger (B) Craft are given in Section 13.

1.1.4 Requirements for craft of less than 24 m not required to comply with the HSC Code are given in Section 14.

1.1.5 Requirements for craft of 24 m or more not required to comply with the HSC Code are given in Section 15.

1.1.6 Additional requirements for yachts that are 500 gt or more are given in Section 16.

1.1.7 The requirements for air cushion vehicles are given in Section 17.

1.1.8 In addition to the requirements of this Chapter, attention should be given to any relevant statutory requirements of the National Authority of the country in which the craft is to be registered.

1.1.9 Consideration will be given to special cases or to arrangements which are equivalent to those required by these Rules.

1.2 Details to be submitted

1.2.1 The plans and information detailed in Chapter 1 are to be submitted before commencement of work.

1.3 Watertight and non-watertight decks

1.3.1 For the purpose of this Section, a non-watertight deck covered by a weathertight structure may be taken as equivalent to a watertight deck. For definitions of the terms watertight and weathertight, *see* Pt 3, Ch 1.

■ *Section 2* Construction and installation

2.1 Installation

2.1.1 All pipes for essential services are to be secured in position to prevent chafing or lateral movement.

2.1.2 Long or heavy lengths of pipe are to be supported by bearers so that no undue load is carried by pipe connections or pumps and fittings to which they are attached.

2.2 Provision for expansion

2.2.1 Suitable provision for expansion is to be made, where necessary, in each range of pipes.

2.2.2 Where expansion pieces are fitted, arrangements are to be provided to protect against over extension and compression. The adjoining pipes are to be suitably aligned, supported, guided and anchored. Where necessary, expansion pieces of the bellows type are to be protected against mechanical damage.

2.3 Miscellaneous requirements

2.3.1 All pipes situated in cargo spaces, chain lockers or other positions where they are liable to mechanical damage are to be efficiently protected.

2.3.2 So far as practicable, pipelines, including exhaust pipes from engines, are not to be routed in the vicinity of switchboards or other electrical appliances in positions where the drip or escape of fluids, gas or steam from joints or fittings could cause damage to the electrical installation. Where it is not practicable to comply with these requirements, drip trays or shields are to be provided as found necessary.

2.4 Testing after installation

2.4.1 After installation on board, all steam, hydraulic, compressed air and other piping systems covered by Ch 1,2.1.3 together with associated fittings which are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

■ *Section 3*
Shell valves and fittings (other than those on scuppers and sanitary discharges)

3.1 Construction

3.1.1 All sea inlet and overboard discharge pipes are to be fitted with valves or cocks secured direct to the shell or to fabricated water boxes attached to the shell.

3.1.2 Distance pieces of short rigid construction and made of approved material may be fitted between the valve and shell. The thickness of such pipes is to be equivalent to shell thickness.

3.1.3 The arrangements are to be such that the section of pipe immediately inboard of the shell valve may be removed without affecting the watertight integrity of the hull.

3.1.4 The valves are to be in accordance with the general requirements for valves given in Ch 1,12.

3.1.5 Shell valves are to be manufactured from non-heat sensitive materials and tested in accordance with the appropriate requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Special consideration will be given to the use of other materials on craft of aluminium or composite construction. Where the valves are manufactured from spheroidal or nodular graphite cast iron they are to be produced at a works approved by Lloyd's Register (hereinafter referred to as 'LR'). Grey cast iron is not acceptable.

3.1.6 Shell valves are to be fitted in accessible positions and are to be capable of being operated from positions which are readily accessible in case of influx of water to the compartment.

3.1.7 Valve hand wheels and cock handles are to be suitably retained on the spindles. Means are to be provided to indicate whether the valve or cock is open or closed.

3.1.8 The scantlings of valves and valve stools fitted with steam or compressed air clearing connections are to be suitable for the maximum pressure to which the valves and stools may be subjected.

3.1.9 Shell valves are to be hydraulically tested before installation in accordance with Ch 1,14.

■ *Section 4*
Bilge pumping and drainage systems

4.1 General

4.1.1 Arrangements are to be made for draining all watertight compartments other than those intended for permanent storage of fluids. Where drainage is not considered necessary, drainage arrangements may be omitted provided the safety of the craft is not impaired.

4.1.2 Pumping arrangements are to be provided having suctions and means of drainage so arranged that any water within any watertight compartment of the craft or any watertight section of any compartment, can be pumped out through at least one suction under all possible conditions of list and trim in the maximum assumed damage condition.

4.1.3 The bilge pumping system is to be designed to prevent water flowing from one watertight compartment to another.

4.1.4 The necessary valves for controlling the bilge suctions are to be capable of being operated from above the watertight deck.

4.1.5 Where a bilge main is not fitted and a compartment is served by a fixed submersible pump in accordance with Section 10, then an additional emergency means of pumping out the compartment is to be provided, *see* Section 6.

4.1.6 Small compartments may be drained by individual hand pump suctions.

4.1.7 The intactness of watertight bulkheads is not to be impaired by the fitting of scuppers discharging to machinery spaces or tunnels from adjacent compartments situated below the highest watertight deck.

4.1.8 Any unattended space for which bilge pumping arrangements are required is to be provided with a bilge level alarm.

4.1.9 Where it is intended to carry flammable or toxic liquids in enclosed spaces, the bilge system shall be designed to prevent pumping of such liquids through piping and pumps in machinery or other spaces where a source of ignition may exist.

■ *Section 5* Bilge drainage of machinery spaces with a propulsion prime mover

5.1 General

5.1.1 The bilge drainage arrangements are to comply with Section 4, except that the arrangements are to be such that any water which may enter this compartment can be pumped out through at least two bilge suctions under all possible conditions of list and trim in the maximum assumed damage condition.

5.1.2 Where a bilge main is fitted, one of the suctions referred to in 5.1.1 is to be a branch bilge suction i.e. a suction connected to the bilge main. The second bilge suction is to be a direct bilge suction as detailed in 8.6.

5.1.3 Where a bilge main is not fitted, the branch bilge suction referred to in 5.1.2 may be replaced by a suction from a submersible bilge pump. The second bilge suction is to be either a second submersible bilge pump or a direct bilge suction as detailed in 8.6.

5.1.4 The emergency bilge drainage arrangements detailed in Section 6 are to be provided where either 5.1.2 or 5.1.3 applies.

5.2 Additional bilge suctions

5.2.1 Additional bilge suctions may be required for the drainage of wells or other recesses.

■ *Section 6* Emergency bilge drainage

6.1 Emergency bilge drainage

6.1.1 In machinery spaces the emergency bilge suction required by 4.1.5 and 5.1.4 is to be led to the largest available power pump, which is not a bilge, propulsion or oil pump, from a suitable low level in the machinery space and is to be fitted with a screw-down non-return valve with an extended spindle and hand wheel situated above the floor plating.

6.1.2 As an alternative to 6.1.1, or in compartments other than machinery spaces, the emergency bilge pumping arrangements may be provided by a portable submersible self-priming pump of capacity not less than that required by 8.3.5.

6.1.3 The pump referred to in 6.1.2 together with its suction and delivery hoses is to be stored in a locker marked 'For emergency use only' and is to be available for immediate use. Arrangements to facilitate safe handling under adverse conditions are to be provided. If the pump is electrically driven it is to be supplied from the emergency switchboard.

■ *Section 7* Size of bilge suction pipes

7.1 Bilge main

7.1.1 Where a bilge main is fitted, its internal diameter d_m is to be not less than that required by the following formula:

$$d_m = 1{,}68\sqrt{L\,(B + D)} + 25 \text{ mm}$$

where

B = breadth of craft, in metres
D = moulded depth to the watertight deck, in metres
L = length of craft, in metres

The actual internal diameter of the bilge main may be rounded off to the nearest pipe size of a recognised standard, but d_m is in no case to be less than 50 mm.

7.2 Branch bilge suctions

7.2.1 The diameter d_b of branch bilge suction pipes is to be not less than that required by the following formula:

$$d_b = 2{,}15\sqrt{C\,(B + D)} + 12{,}5 \text{ mm}$$

where

B and D are as defined in 7.1.1
C = length of compartment, in metres.

The actual internal diameter of branch bilge suction pipes may be rounded off to the nearest pipe size of a recognised standard, but d_b is in no case to be less than 25 mm.

■ *Section 8* Pumps on bilge service

8.1 Number of pumps

8.1.1 For craft fitted with a bilge main, at least two power bilge pumping units are to be provided. One of these units may be worked from the main engines and the other is to be independently driven.

8.1.2 Each unit may consist of one or more pumps connected to the main bilge line, provided that their combined capacity is not less than that required by 8.3.2.

8.1.3 A bilge ejector in combination with a high pressure sea-water pump may be accepted as a substitute for an independent bilge pump as required by 8.1.1.

8.1.4 For craft fitted with fixed submersible bilge pumps, one pump is to be provided for each watertight compartment.

8.1.5 For the bilge pumping requirements for multi-hull craft, *see* Section 12.

8.2 General service pumps

8.2.1 The bilge pumping units or pumps required by 8.1 may also be used for ballast, fire or general service duties of an intermittent nature, but not for pumping fuel or other flammable liquids. These pumps are to be immediately available for bilge duty when required. For the use of bilge pumping units for fire-extinguishing duties, *see* Part 17.

8.3 Capacity of pumps

8.3.1 Each bilge pumping unit is to be connected to the bilge main and is to be capable of giving a speed of water through the Rule size of bilge main of not less than 2 m/s.

8.3.2 To achieve the flow velocity required by 8.3.1, the capacity Q of each bilge pumping unit or bilge pump is to be not less than that required by the following formula:

$$Q = \frac{5,75}{10^3} d_m^2 \quad \text{m}^3\text{/hour}$$

where

d_m is as defined in 7.1.1.

Q = Rule minimum capacity, in m^3/hour.

8.3.3 Where one bilge pumping unit is of slightly less than Rule capacity, the deficiency may be made good by an excess capacity of the other unit. In general, the deficiency is to be limited to 30 per cent.

8.3.4 Where fixed submersible bilge pumps are fitted, the total capacity Q_t of the pumps is to be not less than that required by the following formula:

$$Q_t = \frac{13,8}{10^3} d_m^2 \quad \text{m}^3\text{/hour}$$

where

d_m is as defined in 7.1.1.

Q_t = Rule minimum total capacity, in m^3/hour.

8.3.5 The capacity Q_n of each submersible bilge pump is to be not less than that required by the following formula:

$$Q_n = \frac{Q_t}{(N-1)} \quad \text{m}^3\text{/hour}$$

where

N = number of fixed submersible pumps

Q_t is as defined in 8.3.4

Q_n = Rule minimum submersible pump capacity, in m^3/hour

Q_n is in no case to be less than 8 m^3/hour.

8.4 Self-priming pumps

8.4.1 All power pumps which are essential for bilge services are to be of the self-priming type, unless an approved central priming system is provided for these pumps.

8.5 Pump connections

8.5.1 The connections at the bilge pumps are to be such that one unit may continue in operation when the other unit is being opened up for overhaul.

8.5.2 Pumps required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any pumps so connected is unaffected by the other pumps being in operation at the same time.

8.6 Direct bilge suctions

8.6.1 The direct bilge suction in the machinery space required by 5.1.2 and referred to in 5.1.3 is to be led to an independent power pump, and the arrangements are to be such that the direct suction can be used independently of the main bilge line suctions.

8.6.2 The machinery space direct bilge suction is not to be of a diameter less than that required for the machinery space branch bilge suction and arranged as detailed in 8.6.1.

■ *Section 9* Bilge main arrangements and materials

9.1 General

9.1.1 Bilge mains, branch bilge suctions and bilge overboard discharge arrangements within machinery spaces are to be of steel or other equivalent material.

9.1.2 Where bilge suction pipework outside machinery spaces is manufactured from material sensitive to heat then the arrangements are to be such that pipe failure in one compartment will not render the bilge suction pipework in another compartment inoperable.

9.1.3 Bilge pipework is to be mounted inboard such that in the event of the maximum assumed damage the pipework will remain intact.

9.2 Prevention of communication between compartments

9.2.1 The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another, or of dry cargo spaces, machinery spaces or other dry compartments being placed in communication with the sea or with tanks. For this purpose, screw-down non-return valves are to be provided in the following fittings:

- Bilge valve distribution chests
- Bilge suction hose connections, whether fitted direct to the pump or on the main bilge line.
- Direct bilge suctions and bilge pump connections to the main bilge line.

9.3 Isolation of bilge system

9.3.1 Bilge suction pipes are to be entirely separate from sea inlet pipes or from pipes which may be used for filling or emptying spaces where water or oil is carried.

9.4 Bilge suction strainers

9.4.1 The open ends of bilge suctions are to be enclosed in strum boxes having perforations of not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The boxes are to be so constructed that they can be cleared without breaking any joint of the suction pipe.

■ *Section 10* Submersible bilge pump arrangements

10.1 General

10.1.1 Arrangements are to be such that at least two automatic non-return devices are fitted between the overboard discharge and the watertight space being served by the pump.

10.1.2 One of these devices is to be an automatic non-return valve situated at or near the shell and the other may be a pipework loop taken up to the highest practicable point below the watertight deck. The arrangements are to be effective in the maximum assumed damaged condition.

■ *Section 11* Air, overflow and sounding pipes

11.1 Air pipes

11.1.1 Air pipes are to be fitted to all tanks, cofferdams, tunnels and other compartments which are not fitted with alternative ventilation arrangements.

11.1.2 Air pipes are to be fitted at the opposite end of the tank to that which the filling pipes are placed and/or at the highest part of the tank. Where the tank top is of unusual or irregular profile, special consideration will be given to the number and position of the air pipes.

11.1.3 Air pipes to oil fuel, lubricating oil and other tanks containing flammable liquids which are located in or pass through compartments of high fire risk or on open deck are to be of steel or other equivalent material.

11.2 Termination of air pipes

11.2.1 Air pipes to double bottom tanks, deep tanks extending to the shell plating, or tanks which can be run up from the sea are to be led to above the watertight deck. Air pipes to oil fuel tanks, cofferdams and all tanks which can be pumped up are to be led to the open.

11.2.2 Air pipes from storage tanks containing lubricating or hydraulic oil may terminate in the machinery space, provided that the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces.

11.2.3 The open ends of air pipes to oil fuel tanks are to be situated where no danger will be incurred from issuing oil vapour when the tank is being filled.

11.2.4 The location and arrangement of air pipes for oil fuel service, settling and lubricating oil tanks are to be such that in the event of a broken vent pipe, this does not directly lead to the risk of ingress of sea-water or rainwater.

11.3 Gauze diaphragms

11.3.1 The open ends of air pipes to oil fuel tanks are to be fitted with a wire gauze diaphragm of non-corrodible material which can be readily removed for cleaning or renewal.

11.3.2 Where wire gauze diaphragms are fitted at air pipe openings, the area of the opening through the gauze is to be not less than the cross-sectional area required for the pipe, *see* 11.6.

11.4 Air pipe closing appliances

11.4.1 Closing appliances fitted to tank air pipes are to be of an automatic opening type which will allow the free passage of air or liquid to prevent the tanks being subjected to a pressure or vacuum greater than that for which they are designed, *see also* Pt 3, Ch 4,12.3.

11.4.2 Air pipe closing devices are to be of a type acceptable to LR and are to be tested in accordance with a National or International Standard recognized by LR. The flow characteristic of the closing device is to be determined using water, *see* 11.6.1.

11.4.3 Wood plugs and other devices which can be secured closed are not to be fitted at the outlets.

11.5 Nameplates

11.5.1 Nameplates are to be affixed to the upper ends of all air and sounding pipes.

11.6 Size of air pipes

11.6.1 For every tank which can be filled by on-board pumps, the total cross-sectional area of the air pipes and the air pipe closing devices is to be such that when the tank is overflowing at the maximum pumping capacity available for the tank, it will not be subjected to a pressure greater than that for which it is designed.

11.6.2 In all cases, whether a tank is filled by on-board pumps or other means, the total cross-sectional area of the pipes is to be not less than 25 per cent greater than the effective area of the respective filling pipe.

11.6.3 Air pipes are to be generally not less than 38 mm bore. In the case of small gravity filled tanks smaller bore pipes may be accepted but in no case is the bore to be less than 25 mm.

11.7 Overflow pipes

11.7.1 For all tanks which can be pumped up, overflow pipes are to be fitted where:

(a) The total cross-sectional area of the air pipes is less than that required by 11.6.

(b) The pressure head corresponding to the height of the air pipe is greater than that for which the tank is designed.

11.7.2 In the case of oil fuel tanks, lubricating oil tanks and other tanks containing flammable liquids, the overflow pipe is to be led to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes. Suitable means is to be provided to indicate when overflowing is occurring.

11.7.3 Overflow pipes are to be self draining under normal conditions of trim.

11.7.4 Where overflow sight glasses are provided, they are to be in a vertical dropping line and designed such that the oil does not impinge on the glass. The glass is to be of heat resisting quality and be adequately protected from mechanical damage. Overflow sight glasses are not permitted in oil fuel systems for craft required to comply with the HSC Code.

11.8 Combined air and overflow systems

11.8.1 Where a combined air or overflow system is fitted, the arrangement is to be such that in the event of any one of the tanks being bilged, the other tanks cannot be flooded from the sea through combined air pipes or the overflow main. For this purpose, it will normally be necessary to lead the overflow pipe to a point above the waterline in the maximum assumed damage condition.

11.8.2 Where a common overflow main is provided, the main is to be sized to allow any two tanks connected to that main to overflow simultaneously.

11.9 Sounding arrangements

11.9.1 Provision is to be made for sounding all tanks and the bilges of those compartments which are not at all times readily accessible. The soundings are to be taken as near the suction pipes as practicable.

11.9.2 Sounding devices of an approved type (i.e. level gauge or remote reading level device) may be used in lieu of sounding pipes.

11.9.3 Bilges of compartments which are not at all times readily accessible are to be provided with sounding pipes.

11.9.4 Where fitted, sounding pipes are to be as straight as practicable, and if curved to suit the structure of the craft, the curvature is to be sufficiently easy to permit the ready passage of the sounding rod or chain.

11.9.5 Striking plates of adequate thickness and size are to be fitted under open ended sounding pipes.

11.9.6 Where slotted sounding pipes having closed ends are employed, the closing plugs are to be of substantial construction.

11.9.7 Sounding pipes are to be not less than 32 mm bore.

11.10 Termination of sounding pipes

11.10.1 Except as permitted by 11.11, sounding pipes are to be led to positions above the bulkhead deck which are at all times accessible and, in the case of oil fuel tanks, cargo oil tanks and lubricating oil tanks, the sounding pipes are to be led to safe positions on the open deck.

11.10.2 For closing requirements, *see also* Pt 3, Ch 4,12.3.1.

11.11 Short sounding pipes

11.11.1 In machinery spaces, where it is not practicable to extend sounding pipes as mentioned in 11.10 short sounding pipes extending to readily accessible positions above the platform may be fitted.

11.11.2 Short sounding pipes are not permitted in machinery spaces for tanks containing oil fuel or other flammable oils used in power transmission systems, control and activating systems and heating systems, except as permitted by 11.13.6.

11.11.3 Short sounding pipes may be fitted to tanks used for the storage, distribution and utilization of lubricating oil in machinery spaces. These sounding pipes are to be fitted with cocks having parallel plugs with permanently attached handles located such that, on being released, they automatically close the cocks.

11.12 Elbow sounding pipes

11.12.1 In passenger craft, elbow sounding pipes are not permitted.

11.12.2 Elbow sounding pipes are not to be used for deep tanks, unless the elbows and pipes are situated within closed cofferdams or within tanks containing similar liquids. They may, however, be fitted to other tanks and may be used for sounding bilges, provided that it is not practicable to lead them direct to the tanks or compartments, and subject to any subdivision and damage stability requirements that may apply.

11.12.3 The elbows are to be of heavy construction and adequately supported.

11.13 Sounding arrangements for oil fuel, lubricating oil and other flammable liquids

11.13.1 Safe and efficient means of ascertaining the amount of oil in any storage tank are to be provided.

11.13.2 For oil fuel, lubricating oil and other flammable liquids, closed sounding devices are preferred. Design details of such devices are to be submitted and they are to be tested after fitting on board, to the satisfaction of the Surveyors.

11.13.3 If closed sounding devices are fitted, failure of the device or over filling of the tank is not to result in the release of tank contents. In passenger craft and yachts that are 500 gt or more, such means are not to require penetration below the top of the tank.

11.13.4 Where sounding pipes are used they are not to terminate in any space where risk of ignition or spillage from the sounding pipe might arise. In particular they are not to terminate in public spaces or crew accommodation. Additionally for oil fuel tanks they are not to terminate in machinery spaces. Terminations are to be provided with a suitable means of closure and provision to prevent spillage during refuelling/refilling operations.

11.13.5 Where gauge glasses are used they are to be of the flat type of heat resisting quality, adequately protected from mechanical damage and fitted with self closing valves at the lower ends and at the top ends if these are connected to the tanks below the maximum liquid level.

11.13.6 In yachts and service craft which are not required to comply with the HSC Code, short sounding pipes extending to well-lighted, readily accessible positions above the platform may be fitted in machinery spaces and tunnels. Sounding pipes are to be fitted with cocks having parallel plugs with permanently attached handles located such that, on being released, they automatically close the cocks.

11.13.7 For yachts that are 500 gt or more, where short sounding pipes serve tanks containing oil fuel, an additional sounding device of approved type is to be fitted. In addition, a small diameter self-closing test cock is to be fitted below the cock mentioned in 11.13.6, in order to ensure that the sounding pipe is not under pressure from oil fuel before opening up the sounding pipe.

■ *Section 12* Requirements for multi-hull craft

12.1 General

12.1.1 The requirements of Sections 2 to 11 apply to multi-hull craft except where modified by the requirements of this Section.

12.2 Drainage of raft void spaces

12.2.1 Arrangements are to be provided for venting, sounding and draining raft void spaces generally as required by Sections 1 to 11.

12.2.2 Where the raft void space is located above the water line in the maximum assumed damage condition then it may be drained directly overboard through scuppers fitted with non-return valves.

12.2.3 Raft void spaces which are not located above the water line in the worst expected damage condition are to be provided with pumping arrangements in accordance with Section 4.

12.3 Size of bilge suction pipes

12.3.1 Where a bilge main is fitted in each hull, its internal diameter d_m is to be not less than that required by the following formula:

$$d_m = 1{,}68\sqrt{L\,(B + D)} + 25 \text{ mm}$$

where

B = breadth of a hull in metres
D = moulded depth to the watertight deck, in metres
L = length of craft, in metres

The actual internal diameter of the bilge main may be rounded off to the nearest pipe size of a recognised standard, but d_m is in no case to be less than 50 mm.

12.3.2 The diameter d_b of branch bilge suction pipes is to be not less than that required by the following formula:

$$d_b = 2{,}15\sqrt{C\,(B + D)} + 12{,}5 \text{ mm}$$

where

C = length of compartment, in metres

B and D are as defined in 12.3.1

The actual internal diameter of branch bilge suction pipes may be rounded off to the nearest pipe size of a recognised standard, but d_b is in no case to be less than 25 mm.

12.4 Capacity and number of pumps on bilge main services

12.4.1 Each power bilge pump should be capable of pumping water through the required size of bilge main at a speed of not less than 2 m/s.

12.4.2 To achieve the flow velocity required by 12.4.1, the capacity Q of each bilge pumping unit or bilge pump is to be not less than that required by the following formula:

$$Q = \frac{5{,}75}{10^3}\,d_m^{\,2} \text{ m}^3\text{/hour}$$

where

d_m is as defined in 12.3.1.

12.4.3 Not less than two power bilge pumping units taking suction from the bilge main in each hull are to be provided.

12.4.4 Where the bilge system in each hull is entirely separate then two bilge pumping units in each hull are to be provided.

12.4.5 Where fixed submersible bilge pumps are fitted, the total capacity Q_t of the pumps in each hull is to be not less than that required by the following formula:

$$Q_t = \frac{13{,}8}{10^3}\,d_m^{\,2} \text{ m}^3\text{/hour}$$

where

d_m is as defined in 12.3.1.

12.4.6 The capacity Q_n of each submersible pump is to be not less than that required by the following formula:

$$Q_n = \frac{Q_t}{(N - 1)} \text{ m}^3\text{/hour}$$

where

N = number of fixed submersible pumps in each hull

Q_t is as defined in 12.4.5

Q_n is in no case to be less than 8 m^3/hour.

■ *Section 13* Additional requirements for Passenger (B) Craft

13.1 Bilge pumping arrangements

13.1.1 At least three power bilge pumping units are to be fitted connected to the bilge main, one of which may be driven by the propulsion machinery.

13.1.2 For multi-hull craft the bilge pumping units are to be capable of taking suction from the bilge main in any hull of the craft.

13.1.3 The arrangements are to be such that at least one power bilge pump is to be available for use in all flooding conditions which the craft is required to withstand as follows:

(a) one of the required bilge pumps is to be an emergency pump of a reliable submersible type having a source of power located above the waterline after the craft has sustained the maximum assumed damage; or

(b) the bilge pumps and their sources of power are to be so distributed throughout the length of the craft that at least one pump in an undamaged compartment will be available.

13.1.4 Alternatively fixed submersible bilge pumps may be provided in accordance with the requirements of 8.3.4 for monohull craft or 12.4.5 for multihull craft.

13.1.5 Distribution boxes, cocks and valves in connection with the bilge pumping system are to be so arranged that, in the event of flooding, one of the bilge pumps may take suction from any compartment.

13.1.6 Damage to a pump or its pipe connecting to the bilge main is not to put the bilge system out of action.

13.1.7 When in addition to the main bilge pumping system an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of operating in any compartment under the maximum assumed flooding conditions. In that case only the valves necessary for the operation of the emergency system need be capable of remote operation.

13.1.8 All cocks and valves referred to in 13.1.5 which can be remotely operated are to have their controls at their place of operation clearly marked and are to be provided with means to indicate whether they are open or closed.

■ *Section 14* Requirements for small craft which are not required to comply with the HSC Code

14.1 General

14.1.1 These requirements replace Sections 1 to 10, 12 and 13 of this Chapter. In general the requirements of Section 11 are to be complied with, however 11.4.1 and 11.9.3 do not apply.

14.1.2 Bilge and cooling water pipework systems are to be of an approved material, *see* Ch 1,15.

14.2 Shell valves and fittings

14.2.1 All sea inlet and overboard discharges are to be provided with shut off valves or cocks arranged in positions where they are readily accessible at all times.

14.2.2 Where valves, cocks, inlet chests, distance pieces and other sea connections are made of steel or other approved materials of low corrosion resistance, they are to be suitably protected against wastage.

14.3 Fittings for steel and aluminium hulls

14.3.1 All suction and discharge valves and cocks secured direct to the plating are to be fitted with spigots passing through the plating, but spigots on the valves and cocks may be omitted if these fittings are attached to pads or distance pieces which themselves form spigots in way of the plating.

14.4 Fittings for wood and glass reinforced plastics hulls

14.4.1 The openings in the shell or planking are to have suitably reinforced areas or pads into which the attached fittings are to be spigoted.

14.4.2 Valves or fittings are to be secured with an external ring under the bolt heads. The ring is to be of copper nickel alloy, bronze, dezincification resistant brass or other material approved for use in sea-water.

14.4.3 Valves or cocks up to 50 mm bore may be attached to spigot pieces or hull fittings having an external collar and internal nut.

14.4.4 Valves or cocks over 50 mm bore are to be flanged and attached as per 14.4.2.

14.5 Bilge pumping arrangements

14.5.1 An efficient bilge pumping system is to be fitted having suctions and means of drainage so arranged that any water which may enter any compartment can be pumped overboard.

14.5.2 The system is to be tested on completion of the craft to ensure that all limber holes are free and that under normal conditions of trim any bilge water can drain to an appropriate suction.

14.5.3 The arrangement of pumps, valves, cocks, pipes and sea connections is to be such as to prevent water entering the craft accidentally or the possibility of one watertight compartment being placed in communication with another.

14.5.4 Readily accessible strum boxes are to be fitted at the open ends of tail pipes.

14.5.5 The perforations in the strum boxes are to be not greater than 10 mm diameter and the combined area is to be not less than twice that required for the bilge suction pipe.

14.5.6 Where a collision bulkhead is fitted, the fore peak dry space is to be drained either by a branch suction to the main bilge line or by a manual pump. Alternatively, it may be drained to the adjacent compartment by means of a self closing drain cock which is to be readily accessible under all conditions.

14.5.7 Where a bilge main is fitted, the internal diameter d of the main and the branch suction pipes is to be not less than that required by the following formula:

$$d = \frac{L}{1,2} + 25 \text{ mm}$$

where

L = length of craft, in metres.

14.6 Pumps on bilge service and their connections

14.6.1 Not less than one power pump and one manual bilge pump are to be provided. Both pumps are to be arranged to take suction from the bilge main or suction valve chest as applicable.

14.6.2 The power driven pumps may be used for other services such as deck washing, fire extinguishing or standby cooling water duty but not for pumping oil fuel or other flammable liquids.

14.6.3 The total capacity Q_t of the bilge pumps is to be not less than required by the following formula:

$$Q_t = 1,5 (d - 25) - 6,7 \text{ m}^3\text{/hour}$$

where

d is as defined in 14.5.7

Q_t is in no case to be less than 3 m^3/hour.

14.6.4 A reduction in capacity of one pump may be permitted provided the deficiency is made good by an excess capacity of the other pump or by an additional pump. In no case is this deficiency to be more than 40 per cent of the Rule capacity.

14.6.5 Pumps on bilge service are to be of the self-priming type.

14.6.6 The bilge pumps are to be connected to a common bilge line provided with a branch connection to each compartment.

14.6.7 A non-return valve is to be fitted between each bilge pump and the bilge main.

14.6.8 Non-return valves are to be fitted in each branch bilge suction from the main bilge line.

14.6.9 Power pumps may be driven by the main engine, an auxiliary engine or by an electric motor.

14.6.10 The power pump is to be provided with a suction enabling it to pump directly from the engine space in addition to the suction from the main bilge line. This direct bilge suction is to be controlled by a screw down non-return valve or equivalent.

14.6.11 Manual bilge pumps are to be capable of being operated from readily accessible positions above the waterline.

14.6.12 As an alternative to fitting a bilge main, individual submersible pumps may be fitted. In this case the arrangements are to be in accordance with the requirements of Sections 8, 10 and 12 of this Chapter, as applicable.

■ *Section 15* Requirements for yachts and service craft of 24 m or greater in length, which are not required to comply with the HSC Code

15.1 General

15.1.1 The requirements of Sections 1, 2, 3, 11 and 12 of this Chapter are generally applicable. The remaining Sections concerning the requirements for bilge pumping and drainage systems are replaced by the requirements given in 15.2 to 15.28.

15.2 Bilge pumping and drainage systems

15.2.1 The following requirements replace Sections 4 to 10 of this Chapter.

15.3 Drainage of compartments, other than machinery spaces

15.3.1 All craft are to be provided with efficient pumping plant having the suctions and means for drainage so arranged that any water within any compartment of the craft, or any watertight section of any compartment, can be pumped out through at least one suction when the craft is on an even keel and is either upright or has a list of not more than 5°. For this purpose, wing suctions will generally be necessary, except in short, narrow compartments where one suction can provide effective drainage under the above conditions.

15.3.2 In the case of dry compartments, the suctions required by 15.3.1 are, except where otherwise stated, to be branch bilge suctions, i.e. suctions connected to a main bilge line.

15.4 Tanks and cofferdams

15.4.1 All tanks (including double bottom tanks), whether used for water ballast, oil fuel or liquid cargoes, are to be provided with suction pipes, led to suitable power pumps, from the after end of each tank.

15.4.2 In general, the drainage arrangements are to be in accordance with 15.3. However, where the tanks are divided by longitudinal watertight bulkheads or girders into two or more tanks, a single suction pipe, led to the after end of each tank, will normally be acceptable.

15.4.3 Similar drainage arrangements are to be provided for cofferdams, except that the suctions may be led to the main bilge line.

15.5 Fore and after peaks

15.5.1 Where the peaks are used as tanks, a power pump suction is to be led to each tank, except in the case of small tanks used for the carriage of domestic fresh water, where hand pumps may be used.

15.5.2 Where the peaks are not used as tanks, and main bilge line suctions are not fitted, drainage of both peaks may be effected by hand pump suctions, provided that the suction lift is well within the capacity of the pumps. Drainage of the after peak may be effected by means of a self-closing cock fitted in a well lighted and readily accessible position.

15.5.3 Pipes piercing the collision bulkhead are to be fitted with suitable valves secured to the bulkhead. The valves are to be operable from above the freeboard deck.

15.6 Spaces above fore peaks, after peaks and machinery spaces

15.6.1 Provision is to be made for the drainage of the chain locker and watertight compartments above the fore peak tank by hand or power pump suctions.

15.6.2 Steering gear compartments or other small enclosed spaces situated above the after peak tank are to be provided with suitable means of drainage, either by hand or power pump bilge suctions.

15.6.3 The compartments referred to in 15.6.2 may be drained by scuppers of not less than 38 mm bore, discharging to the tunnel or machinery space and fitted with self-closing cocks situated in well lighted and visible positions.

15.7 Maintenance of integrity of bulkheads

15.7.1 The intactness of the machinery space bulkheads, and of tunnel plating required to be of watertight construction, is not to be impaired by the fitting of scuppers discharging to machinery space or tunnels from adjacent compartments which are situated below the bulkhead deck.

15.7.2 No drain valve or cock is to be fitted to the collision bulkhead. Drain valves or cocks are not to be fitted to other watertight bulkheads if alternative means of drainage are practicable.

15.8 Bilge drainage of machinery space

15.8.1 The bilge drainage arrangements in the machinery space are to comply with 15.3 except that the arrangements are to be such that any water which may enter this compartment can be pumped out through at least two bilge suctions when the craft is on an even keel, and is either upright or has a list of not more than 5°. One of these suctions is to be a branch bilge suction, i.e. a suction connected to the main bilge line, and the other is to be a direct bilge suction, i.e. a suction led direct to an independent power pump.

15.9 Separate machinery spaces

15.9.1 Where the machinery space is divided by watertight bulkheads to separate the auxiliary engine room(s) from the main engine room, the bilge drainage arrangements for the auxiliary engine room(s) are to be the same as for compartments, other than machinery spaces, referred to in 15.3.1.

15.9.2 In addition to the requirements of 15.9.1, at least one direct suction, led to an independent power pump, is to be fitted in each compartment.

15.10 Machinery space with double bottom

15.10.1 Where the double bottom extends the full length of the machinery space and forms bilges at the wings, it will be necessary to provide one branch and one direct bilge suction at each side.

15.10.2 Where the double bottom plating extends the full length and breadth of the compartment, one branch bilge suction and one direct bilge suction are to be led to each of two bilge wells, situated one at each side.

15.10.3 Where there is no double bottom and the rise of floor is not less than 5°, one branch and one direct bilge suction are to be led to accessible positions as near to the centreline as practicable.

15.11 Machinery space – Emergency bilge drainage

15.11.1 In addition to the bilge suctions detailed in 15.8 and 15.9, an emergency bilge suction is to be provided in each main machinery space. This suction is to be led to the main cooling water pump from a suitable low level in the machinery space and is to be fitted with a screw-down non-return valve having the spindle so extended that the hand wheel is not less than 460 mm above the bottom platform.

15.11.2 Where two or more cooling water pumps are provided, each capable of supplying cooling water for normal power, only one pump need be fitted with an emergency bilge suction.

15.11.3 Where main cooling water pumps are not suitable for bilge pumping duties, the emergency bilge suction is to be led to the largest available power pump, which is not a bilge pump.

15.11.4 Emergency bilge suction valve nameplates are to be marked ‘For emergency use only’.

15.12 Sizes of bilge suction pipes

15.12.1 The diameter, d_m, of the main bilge line is to be not less than that required by the following formula, to the nearest 5 mm, but in no case is the diameter to be less than that required for any branch bilge suction:

$$d_m = 1{,}68\sqrt{L\,(B + D)} + 25 \text{ mm}$$

where

d_m = internal diameter of main bilge line, in mm
B = greatest moulded breadth of craft, in metres
D = moulded depth to bulkhead deck, in metres
L = Rule length of craft in metres.

15.12.2 The diameter d_b, of branch bilge suction pipes to cargo and machinery spaces is to be not less than required by the following formula, to the nearest 5 mm, but in no case is the diameter of any suction to be less than 50 mm:

$$d_b = 2{,}15\sqrt{C\,(B + D)} + 25 \text{ mm}$$

where

d_b = internal diameter of branch bilge suction, in mm
C = length of compartment, in metres
B and D are as defined in 15.12.1.

15.12.3 The direct bilge suctions in the machinery space are not to be of a diameter less than that required for the main bilge line.

15.12.4 For sizes of emergency bilge suctions, *see* 15.11.

15.13 Distribution chest branch pipes

15.13.1 The area of each branch pipe connecting the bilge main to a distribution chest is to be not less than the sum of the areas required by the Rules for the two largest branch bilge suction pipes connected to that chest, but need not be greater than that required for the main bilge line.

15.14 Pumps on bilge service and their connections

15.14.1 At least two power bilge pumping units are to be provided in the machinery space. One of these units may be worked from the main engines and the other is to be independently driven.

15.14.2 Each unit may consist of one or more pumps connected to the main bilge line, provided that their combined capacity is adequate.

15.14.3 A bilge ejector in combination with a high pressure sea-water pump may be accepted as a substitute for an independent bilge pump as required by 15.14.1.

15.14.4 Special consideration will be given to the number of pumps for small craft and, in general, if there is a class notation restricting a small craft to harbour or river service, a hand pump may be accepted in lieu of one of the bilge pumping units.

15.15 General service pumps

15.15.1 The bilge pumping units, or pumps, required by 15.14 may also be used for ballast, fire or general service duties of an intermittent nature, but they are to be immediately available for bilge duty when required.

15.16 Capacity of pumps

15.16.1 Each bilge pumping unit is to be connected to the main bilge line and is to be capable of giving a speed of water through the Rule size of main bilge pipe of not less than 122 m/min.

15.16.2 The capacity of each bilge pumping unit or bilge pump is to be not less than required by the following formula:

$$Q = \frac{5,75}{10^3} d_m{}^2$$

where

d_m = Rule internal diameter of main bilge line, in mm
Q = capacity, in m^3/hour.

15.16.3 Where one bilge pumping unit is of slightly less than Rule capacity, the deficiency may be made good by an excess capacity of the other unit. In general, the deficiency is to be limited to 30 per cent.

15.17 Self-priming pumps

15.17.1 All power pumps which are essential for bilge services are to be of the self-priming type, unless an approved central priming system is provided for these pumps. Details of this system are to be submitted.

15.17.2 Cooling water pumps having emergency bilge suctions need not be of the self-priming type.

15.18 Pump connections

15.18.1 The connections at the bilge pumps are to be such that one unit may continue in operation when the other unit is being opened up for overhaul.

15.18.2 Pumps required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any pumps so connected is unaffected by the other pumps being in operation at the same time.

15.19 Direct bilge suctions

15.19.1 The direct bilge suctions in the machinery space are to be led to independent power pumps, and the arrangements are to be such that these direct suctions can be used independently of the main bilge line suctions.

15.20 Main bilge line suctions

15.20.1 Suctions from the main bilge line, i.e. branch bilge suctions, are to be arranged to draw water from any hold or machinery compartment within the craft, excepting small spaces such as those mentioned in 15.5 and 15.6 where manual pump suctions are accepted, and are not to be of smaller diameter than that required by the formula in 15.12.2.

15.21 Prevention of communication between compartments

15.21.1 The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another, or of dry cargo spaces, machinery spaces or other dry compartments being placed in communication with the sea or with tanks. For this purpose, screw-down non-return valves are to be provided in the following fittings:

- Bilge valve distribution chests.
- Bilge suction hose connections, whether fitted directly to the pump or on the main bilge line.
- Direct bilge suctions and bilge pump connections to main bilge line.

15.22 Isolation of bilge system

15.22.1 Bilge pipes which are required for draining cargo or machinery spaces are to be entirely distinct from sea inlet pipes or from pipes which may be used for filling or emptying spaces where water or oil is carried. This does not, however, exclude a bilge ejection connection, a connecting pipe from a pump to its suction valve chest, or a deep tank suction pipe suitably connected through a change-over device to a bilge, ballast or oil line.

15.23 Machinery space suctions – Mud boxes

15.23.1 Suctions for bilge drainage in machinery spaces and tunnels, other than emergency suctions, are to be led from easily accessible mud boxes fitted with straight tail pipes to the bilges and having covers secured in such a manner as to permit their being expeditiously opened or closed. Strum boxes are not to be fitted to the lower ends of these tail pipes or to the emergency bilge suctions.

15.24 Hold suctions – Strum boxes

15.24.1 The open ends of bilge suctions in holds and other compartments outside machinery spaces and tunnels are to be enclosed in strum boxes having perforations of not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The boxes are to be so constructed that they can be cleared without breaking any joint of the suction pipe.

15.25 Tail pipes

15.25.1 The distance between the foot of all bilge tail pipes and the bottom of the bilge well is to be adequate to allow a full flow of water and to facilitate cleaning.

15.26 Location of fittings

15.26.1 Bilge valves, cocks and mud boxes are to be fitted at, or above, the machinery space platforms.

15.26.2 Where relief valves are fitted to pumps having sea connections, these valves are to be fitted in readily visible positions above the platform. The arrangements are to be such that any discharge from the relief valves will also be readily visible.

15.27 Bilge pipes in way of double bottom tanks

15.27.1 Bilge suction pipes are not to be led through double bottom tanks if it is possible to avoid doing so.

15.27.2 Bilge pipes which have to pass through these tanks are to have a minimum wall thickness of 6,3 mm. The thickness of pipes made from material other than steel will be specially considered.

15.27.3 Expansion bends, not glands, are to be fitted to these pipes within the tanks, and the pipes are to be tested, after installation, to the same pressure as the tanks through which they pass.

15.28 Hold bilge non-return valves

15.28.1 Where non-return valves are fitted to the open ends of bilge suction pipes in cargo holds in order to decrease the risk of flooding, they are to be of an approved type which does not offer undue obstruction to the flow of water.

■ *Section 16*
Additional requirements for yachts that are 500 gt or more

16.1 General

16.1.1 Yachts that are 500 gt or more are to comply with Section 15 of this Chapter and in addition the following requirements.

16.2 Location of bilge pumps and bilge main

16.2.1 At least three power bilge pumps are to be provided, one of which may be operated from the main engines. Wherever practicable they are to be located in separate watertight compartments which will not readily be flooded by the same damage. If the engines are in two or more watertight compartments, the bilge pumps are to be distributed throughout these compartments so far as possible.

16.2.2 Where compliance with 16.2.1 is impractical, two independently driven bilge pumps may be accepted provided they are located in separate watertight compartments. If both pumps are necessarily located in the machinery space then one is to be of the submersible type with its source of power located above the bulkhead deck.

16.2.3 The bilge main is to be so arranged that no part is situated nearer the side of the craft than $B/5$, measured at right angles to the centreline at the level of the deepest sub-division load line, where B is the breadth of the craft.

16.2.4 Where any bilge pump or its pipe connection to the bilge main is situated outboard of the $B/5$ line, then a non-return valve is to be provided in the pipe connection at the junction with the bilge main.

16.2.5 Each independent bilge pump is to have a direct bilge suction from the space in which it is situated, but not more than two such suctions are required in any one space. The suctions are to be arranged such that each side of the space is fitted with at least one suction.

16.3 Prevention of communication between compartments in the event of damage

16.3.1 Provision is to be made to prevent the compartment served by any bilge suction pipe being flooded, in the event of the pipe being severed, or otherwise damaged by collision or grounding in any other compartment. For this purpose, where any part of a branch bilge pipe is situated outboard of the *B*/5 line or in a duct keel, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

16.4 Arrangement and control of bilge valves

16.4.1 Distribution boxes, valves and cocks in connection with the bilge pumping arrangements are to be so arranged that, in the event of flooding, one of the bilge pumps may be operative on any compartment.

16.4.2 Where there is only one system of pipes common to all pumps, the arrangements are to be such that if the machinery space or other compartment is flooded then it is possible to operate the necessary valves and cocks in order to take suction from that compartment. For this purpose it may be necessary to arrange for remote control of the bilge suction valves from above the bulkhead deck.

16.4.3 Where, in addition to the main bilge pumping system, an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of operating on any compartment under flooding conditions. In this case, only the valves and cocks necessary for the operation of the emergency system need to be capable of being operated from above the bulkhead deck.

16.4.4 All valves and cocks mentioned in 16.4.2 which can be operated from above the bulkhead deck are to have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

16.5 Cross flooding arrangements

16.5.1 Where divided deep tanks or side tanks are provided with cross flooding arrangements to limit the angle of heel after side damage, the arrangements are to be self-acting where practicable. In any case, where controls to cross flooding fittings are provided, they are to be operable from above the bulkhead deck.

■ *Section 17* Requirements for Air Cushion Vehicles

17.1 General

17.1.1 At least three copies of the following diagrammatic plans are to be submitted together with a general description of each system, indicating operating pressures and temperatures, etc., safety devices incorporated and means of protection against corrosion and contamination:

- Oil fuel.
- Lubricating oil.
- Hydraulic and pneumatic systems.
- Pumping arrangements for draining and trimming.
- Air filtering to power units.

17.1.2 Reference is to be made to the *Guidance Notes and Requirements for the Classification of Air Cushion Vehicles (ACV) 1970*.

Section

■ *Section 1* Application

1.1 Applicability of requirements

1.1.1 The requirements of Sections 2 to 8 of this Chapter apply to piping systems on mono-hull and multi-hull craft except where modified by Sections 9 to 11 as applicable.

1.1.2 Special requirements for multi-hull craft are given in Section 9.

1.1.3 These requirements satisfy the relevant design and construction requirements of the HSC Code. They are also applicable to yachts and service craft of more than 24 m not required to comply with the Code.

1.1.4 Requirements for Passenger (A) Craft are given in Section 10.

1.1.5 Requirements for small craft not required to comply with the HSC Code are given in Section 11.

1.1.6 In addition to the requirements of this Chapter, attention is to be given to any relevant statutory requirements of the National Authority of the country in which the craft is to be registered.

■ *Section 2* General requirements

2.1 General

2.1.1 The maximum working pressure in any part of a fluid system is not to be greater than the design pressure.

2.1.2 Where the design pressure of a system component, such as a valve or a fitting, is less than that for the pipe or tubing, the system pressure is to be limited to the lowest of the component design pressures. Every system which may be exposed to pressures higher than the design pressure is to be safeguarded by appropriate relief devices.

2.1.3 Materials used in piping systems are to be compatible with the fluid conveyed and due regard given to the risk of fire. Non-metallic piping material may be permitted in certain systems, provided the integrity of the hull and watertight decks and bulkheads is maintained.

2.1.4 The design of pipework systems is to be in accordance with the requirements of Chapter 1.

■ *Section 3* Oil fuel storage

3.1 Flash point

3.1.1 The flash point (closed cup test) of oil fuel for use in craft classed for unrestricted service is in general to be not less than 60°C. For emergency generator engines, a flash point of not less than 43°C is permissible.

3.1.2 Oil fuel with a flash point lower than 60°C may be used in craft intended for restricted service where it can be demonstrated that the temperature of machinery spaces will always be 10°C below the flash point of the oil fuel.

3.1.3 The use of oil fuel with a flash point below 43°C is not recommended. However, oil fuel with a lower flash point, but not lower than 35°C, may be used in gas turbines only subject to compliance with the provisions specified in Section 5.

3.1.4 Proposals for the use or carriage of oil fuel with a lower flash point will be specially considered.

3.2 Oil fuel storage arrangements

3.2.1 Tanks containing oil fuel are to be separated from passenger, crew and baggage compartments by vapour-proof enclosures or cofferdams which are suitably ventilated and drained.

3.2.2 Oil fuel tanks are not to be located in or adjacent to major fire hazard areas.

3.2.3 Oil fuel is not to be carried forward of the area for which public spaces or crew accommodation are permitted.

3.2.4 No oil fuel tank is to be situated where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces.

3.2.5 Safe and efficient means of ascertaining the amount of oil fuel contained in any oil fuel tank is to be provided, *see also* Ch 2,11.9 to 11.12.

3.2.6 Oil fuel tanks are to be provided with self-closing valves or cocks for draining water from the bottom of the tanks.

3.2.7 As far as practicable, all parts of the oil fuel system containing heated oil under pressure exceeding 2 bar are not to be placed in a concealed position such that defects and leakage cannot be readily observed. The machinery spaces in way of such parts of the oil fuel system are to be adequately illuminated.

3.2.8 Oil fuel tanks are to be provided with oil-tight drip trays of sufficient capacity having suitable drainage arrangements.

3.2.9 In general oil fuel tanks are not to be used for carriage of water ballast. Where this is unavoidable the fuel transfer system is to be isolated from the ballast system and either oily water separating equipment is to be installed, or discharge to shore facilities provided, in accordance with the requirements of the *International Convention for the Prevention of Pollution from Ships* in force.

3.3 Oil fuel storage arrangements for yachts and service craft of 24 m or greater in length, which are not required to comply with the HSC Code

3.3.1 Oil fuel tanks are normally to be located outside machinery spaces and other areas of major fire hazard.

3.3.2 Where structural tanks are located adjacent to machinery spaces they are to be arranged such that the area of the tank common with the machinery space is kept to a minimum. In craft constructed of aluminium or other heat sensitive material the tanks are to be suitably protected against the effect of fire in the machinery space.

3.3.3 Where free standing tanks are fitted in machinery spaces they are to be of steel or equivalent material and positioned in an oil tight drip tray of ample size having suitable drainage arrangements to a spill oil tank.

3.3.4 For yachts that are 500 gt or more, free standing oil fuel tanks are not to be fitted in machinery spaces, *see* Pt 17, Ch 3,3.17.3.

3.3.5 The requirements of 3.2.4 to 3.2.8 are to be complied with. Where free standing tanks are fitted they are to comply with the requirements of 11.3.1 to 11.3.3.

3.4 Unattended machinery

3.4.1 Where machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, the requirements of 3.4.2 to 3.4.5 apply.

3.4.2 Where daily service tanks are filled automatically or by remote control, means are to be provided to prevent overflow spillages.

3.4.3 Other equipment which treats flammable liquid automatically, such as oil fuel purifiers, are to have arrangements to prevent spillage of the liquid through overflow or malfunction of seals.

3.4.4 Alarms are to be provided for purifier broken water seal and high oil inlet temperature.

3.4.5 Where daily service oil fuel tanks or settling tanks are fitted with heating arrangements, a high temperature alarm is to be provided if the flash point of the oil can be exceeded. This alarm is to be separate from the temperature control system.

3.4.6 Oil fuel service tanks are to be provided with high and low level alarms. Where a common overflow tank is fitted, a high level alarm in the common overflow tank may be accepted.

3.4.7 Oil and gas dual-fired systems for boilers and engines are to be provided with indication to show which fuel is in use.

■ *Section 4* Oil fuel systems

4.1 Oil fuel supply to main and auxiliary engines

4.1.1 Two or more filters are to be fitted in the oil fuel supply lines to the main and auxiliary engines, and the arrangements are to be such that any filter can be cleaned without interrupting the supply of filtered oil fuel to the engines.

4.2 Booster pumps

4.2.1 Where an oil fuel booster pump is fitted, which is essential to the operation of the main engine, a standby pump is to be provided.

4.2.2 The standby pump is to be connected ready for immediate use, but where two or more main engines are fitted, each with its own pump, a complete spare pump may be accepted provided that it is readily accessible and can easily be installed.

4.3 Fuel valve cooling pumps

4.3.1 Where pumps are provided for fuel valve cooling, the arrangements are to be in accordance with 4.2.1 and 4.2.2.

4.4 Transfer pumps

4.4.1 Where a power driven pump is necessary for transferring oil fuel, a standby pump is to be provided and connected ready for use. The standby pump may be a manual pump. Alternatively, emergency connections may be made to another suitable power driven pump.

4.5 Control of pumps

4.5.1 All independently driven oil fuel transfer and pressure pumps are to be capable of being stopped locally and from a position outside of the space in which they are located. The remote stop position is always to be accessible in the event of fire occurring in the space in which these pumps are located.

4.6 Relief valves on pumps

4.6.1 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be in close circuit, i.e. arranged to discharge back to the suction side of the pump and to effectively limit the pump discharge pressure to the design pressure of the system.

4.7 Pump connections

4.7.1 Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, in order that any pump may be shut off for opening up and overhauling.

4.8 Low pressure pipes

4.8.1 Transfer, suction and other low pressure oil pipes and all pipes passing through oil storage tanks are to be suitable for a working pressure of not less than 7 bar.

4.9 Valves on deep tanks and their control arrangements

4.9.1 Every oil fuel suction pipe from a storage, settling or daily service tank situated above the double bottom, and every oil fuel levelling pipe, is to be fitted with a valve or cock secured to the tank.

4.9.2 In machinery spaces such valves and cocks are to be capable of being closed locally and from positions outside these spaces which will always be accessible in the event of fire occurring in these spaces. Instructions for closing the valves or cocks are to be indicated at the valves and cocks and at the remote control positions.

4.9.3 In the case of tanks of less than 0,5 m^3, consideration will be given to the omission of remote controls for craft not required to comply with the HSC Code.

4.9.4 Every oil fuel suction pipe which is led into the machinery spaces, from a deep tank outside these spaces, is to be fitted in the machinery space with a valve controlled as in 4.9.2 except where the valve on the tank is already capable of being closed from an accessible position above the bulkhead deck.

4.9.5 Where the filling pipes to deep oil tanks are not connected to the tanks near the top, they are to be provided with non-return valves at the tanks or with valves or cocks fitted and controlled as in 4.9.2.

4.10 Filling arrangements

4.10.1 Filling stations are to be isolated from other spaces and are to be efficiently drained and ventilated.

4.10.2 Provision is to be made against over-pressure in the filling pipelines. Any relief valve fitted for this purpose is to discharge to an overflow tank or other safe position.

4.11 Precautions against fire

4.11.1 Pipes, valves and couplings conveying flammable fluids are to be installed, screened or otherwise suitably protected, to avoid spray or leakages onto hot surfaces, into machinery air intakes, or other sources of ignition such as electrical equipment. The number of joints in such systems is to be kept to a minimum.

■ *Section 5* Low flash point fuels

5.1 General

5.1.1 For craft having oil fuel with a flash point below 43°C the arrangements for the storage, distribution and utilisation of the oil fuel are to be such that the safety of the craft and persons on board is preserved, having regard to fire and explosion hazards. The arrangements are to comply with Sections 3, 4 and 5.1.2 to 5.1.6.

5.1.2 Tanks for the storage of such oil fuel are to be located outside any machinery space and at a distance of not less than 760 mm inboard from the shell and bottom plating, and from decks and bulkheads.

5.1.3 The spaces in which oil fuel tanks are located are to be mechanically ventilated using exhaust fans providing not less than six air changes per hour. The fans are to be such as to avoid the possibility of ignition of flammable gas air mixtures. Suitable wire mesh guards are to be fitted over inlet and outlet ventilation openings. The outlets for such exhausts are to discharge to a safe position.

5.1.4 A fixed vapour detection system is to be installed in each space through which oil fuel lines pass, with alarms provided at a continuously manned control station.

5.1.5 Safe and efficient means of ascertaining the amount of oil fuel contained in any tank is to be provided. Gauge glasses are not to be used. Other means of ascertaining the amount of oil fuel contained in any tank may be permitted if such means do not require penetration below the top of the tank, and providing their failure or overfilling of the tanks will not permit the release of oil fuel.

5.1.6 Vessel to shore oil fuel connections are to be of closed type and suitably grounded during bunkering operations.

5.1.7 Air pipes shall discharge to a safe position and terminate with flame arresters in accordance with MSC/ Circ. 677.

■ *Section 6*
Lubricating/hydraulic oil systems

6.1 Lubricating oil arrangements

6.1.1 The arrangements for the storage, distribution and utilization of oil used in pressure lubrication systems in machinery spaces and, whenever practicable, in auxiliary machinery spaces are to comply with the provisions of 3.2 (except 3.2.2), 3.4 and 4.9 (except 4.9.3).

6.1.2 Tanks containing lubricating oil located within major fire hazard areas are to be of steel or other equivalent material.

6.1.3 Where lubricating oil tanks have a capacity of less than 0,5 m^3, consideration will be given to relaxing the requirements for remote controls to be fitted.

6.1.4 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the engine or reducing supply of filtered oil to the engine. Proposals for an automatic by-pass for emergency purposes in high speed engines are to be submiited for consideration.

6.1.5 In addition, craft of 24 m or greater in length are to comply with the requirements of 4.5 to 4.7.

6.2 Arrangements for other flammable oils

6.2.1 The arrangements for storage, distribution and utilization of other flammable oils employed under pressure in power transmission, control/activating and heating systems, in locations where means of ignition are present, are to comply with the applicable provisions of 6.1.

6.3 Lubricating/hydraulic oil standby arrangements

6.3.1 Where lubricating oil for the main engine(s) is circulated under pressure, a standby lubricating oil pump is to be provided where the following conditions apply:
(a) The lubricating oil pump is independently driven and the total output of the main engine(s) exceeds 500 kW.
(b) One main engine with its own pump is fitted and the output of the engine exceeds 500 kW.
(c) More than one engine each with its own lubricating oil pump is fitted and the output of each engine exceeds 500 kW.

6.3.2 The standby pump is to be of sufficient capacity to maintain the supply of oil for normal conditions with any one pump out of action. The pump is to be fitted and connected ready for immediate use, except that where the conditions referred to in 6.3.1(c) apply, a complete spare pump may be accepted. In all cases, satisfactory lubrication of the engines is to be ensured while starting and manoeuvring.

6.3.3 Similar provisions to those of 6.3.1 and 6.3.2 are to be made where separate lubricating/hydraulic oil systems are employed for piston cooling, reduction gears, oil operated couplings controllable pitch propellers and steering systems etc., unless approved alternative arrangements are provided.

6.3.4 Independently driven pumps of rotary type are to be fitted with a non-return valve on the discharge side of the pump.

6.4 Lubricating oil contamination

6.4.1 The materials used in the storage and distribution of lubricating oil are to be selected such that they do not introduce or modify the properties of the oil. The use of cadmium or zinc in lubricating oil systems where they may come into contact with the oil is not permitted.

6.4.2 Arrangements are to be made for each forced lubrication system, renovation system, ready to use tank(s) and their associated rundown lines to drain tanks to be flushed after system installation and prior to running of machinery. The flushing arrangements are to be in accordance with the equipment manufacturer's procedures and recommendations.

6.4.3 The design and construction of engine and gear box piping arrangements are to prevent as far as practicable, contamination of engine lubricating oil systems by leakage of cooling water or from bilge water where engines or gearboxes are partly installed below the lower platform.

6.4.4 Where a lubricating oil filling pipe and cap are provided for engines and other machinery, provision is to be made for the topping up oil to pass through a gauze strainer. The caps are to be capable of being secured in the closed position.

6.4.5 Sampling points are to be provided that enable samples of lubricating oil to be taken in a safe manner. The sampling arrangements are to have the capability to provide samples when machinery is running and are to be provided with valves and cocks of the self-closing type and located in positions as far removed as possible from any heated surface or electrical equipment.

■ *Section 7* Engine cooling water systems

7.1 General

7.1.1 The cooling arrangements provided are to be adequate to maintain all lubricating and hydraulic fluid temperatures within the manufacturer's recommended limits.

7.2 Main supply

7.2.1 Provision is to be made for an adequate supply of cooling water to the main propelling machinery and essential auxiliary engines, also to the lubricating oil and fresh water coolers and air coolers for electric propelling machinery, where these coolers are fitted. The cooling water pump(s) may be worked from the engines or be driven independently.

7.3 Standby supply

7.3.1 Provision is also to be made for a separate supply of cooling water from a suitable independent pump of adequate capacity.

7.3.2 The following arrangements are acceptable depending on the purpose for which the cooling water is intended:

(a) Where only one main engine is fitted, the standby pump is to be connected ready for immediate use.

(b) Where more than one main engine is fitted, each with its own pump, a complete spare pump of each type may be accepted.

(c) Where fresh water cooling is employed for main and/or auxiliary engines, a standby fresh water pump need not be fitted if there are suitable emergency connections from a salt water system.

(d) Where each auxiliary engine is fitted with a cooling water pump, standby means of cooling need not be provided. Where, however, a group auxiliary engine is supplied with cooling water from a common system, a standby cooling water pump is to be provided for this system.

This pump is to be connected ready for immediate use and may be a suitable general service pump.

7.4 Selection of standby pumps

7.4.1 When selecting a pump for standby purposes, consideration is to be given to the maximum pressure which it can develop if the overboard discharge valve is partly or fully closed. Where necessary, water boxes, etc., are to be protected against inadvertent over-pressure by an approved device.

7.5 Relief valves on main cooling water pumps

7.5.1 Where cooling water pumps can develop a pressure head greater than the design pressure of the system, they are to be provided with relief valves on the pump discharge to effectively limit the pump discharge pressure to the design pressure of the system.

7.6 Sea inlets

7.6.1 Not less than two sea inlets are to be provided for the pumps supplying the sea water cooling system, one for the main pump and one for the standby pump. Alternatively, the sea inlets may be connected to a suction line available to main and standby pumps.

7.6.2 Where standby pumps are not connected ready for immediate use (*see* 7.3.2(b) and (d)), the main pump is to be connected to both sea inlets.

7.6.3 The auxiliary cooling water sea inlets are to be located one on each side of the craft.

7.7 Strainers

7.7.1 Where sea water is used for the direct cooling of the main engines and essential auxiliary engines, the cooling water suction pipes are to be provided with strainers which can be cleaned without interruption to the cooling water supply.

■ *Section 8* Miscellaneous machinery

8.1 General

8.1.1 Alarms and safeguards are indicated in Table 1.8.1.

Table 1.8.1 Miscellaneous machinery: Alarms and safeguards

Item	Alarm	Note
Coolant tanks level	Low	—
Sludge tanks level	High	—
Feed water tanks level	Low	Service tank only
Hydraulic control system pressure	Low	—
Pneumatic control system pressure	Low	—

■ *Section 9* Special requirements for multi-hull craft

9.1 General

9.1.1 The requirements of Sections 1 to 8 are generally applicable to multi-hull craft except where these are modified by the requirements of this Section.

9.1.2 Where the machinery piping arrangements in each hull of a multi-hull craft are separate, the machinery piping and standby requirements for each hull are to be as detailed in 6.3.1(c) and 7.3.2(b), i.e. the requirements for a twin-engined mono-hull craft apply.

9.1.3 Where a multi-hull craft cannot navigate safely with the main propulsion machinery in one hull out of action, the machinery piping and standby requirements are to be as detailed in 6.3.1(a) or (b), and 7.3.2(a), i.e. the requirements for a single-engined mono-hull craft apply to the machinery in each hull.

■ *Section 10* Requirements for Passenger (A) Craft

10.1 General

10.1.1 The requirements of Sections 1 to 9 apply except that the standby machinery arrangements detailed in Sections 6 and 7 are not required.

■ *Section 11* Requirements for small craft which are not required to comply with the HSC Code

11.1 General

11.1.1 The requirements of this Section replace Sections 3.2 to 3.4 and 4, 5, 6 and 7 of this Chapter, *see also* Ch 1,15.

11.2 Oil fuel system

11.2.1 Where a power driven oil fuel transfer pump is fitted, it is to be capable of being stopped from a position outside the space which will always be accessible in the event of fire occurring in the compartment in which the pump is situated, as well as from the compartment itself.

11.2.2 Where a power driven pump is necessary for transferring oil fuel, a standby pump is to be provided and connected ready for use.

11.3 Separate oil fuel tanks

11.3.1 Except for very small tanks separate oil fuel tanks are to be not less than 3 mm in thickness. The seams are to be welded or brazed. Steel tanks are to be protected from corrosion.

11.3.2 Before installation, all tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

11.3.3 Separate oil fuel tanks are to be securely fixed in position, and located as remote as practicable from exhaust manifolds and exhaust pipes or other hot surfaces and not above any electrical apparatus. Where this cannot be avoided, a drip tray is to be fitted under the tank and extended sufficiently to catch any drips from fittings attached to the tank.

11.3.4 Oil fuel tanks are not to be fitted above or adjacent to oil fired heaters, cooking stoves, equipment using naked flames or electrical equipment unless this is suitably constructed or enclosed.

11.4 Oil fuel filling

11.4.1 The filling pipe is to be of metallic construction and is to be a permanent fixture led from the deck and secured to the tank by an approved connection. A screwed cap and name plate inscribed 'Oil Fuel' is to be provided at the filling point.

11.4.2 Flexible hoses are not permitted as filling pipes. In wood or composite craft short lengths may be employed at the deck connection to accommodate any movement between the tank and the deck fitting.

11.5 Oil fuel supply

11.5.1 Provision is to be made for efficient filtration of the oil fuel supply to the engine.

11.6 Oil fuel valves and cocks

11.6.1 Outlet valves or cocks are to be fitted to all deep tanks. The valves are to be fitted directly to the tank plating and are to be capable of being closed locally and from positions which will always be readily accessible in the event of fire.

11.6.2 Valve covers are to be so constructed that they will not become slack when the valves are operated.

11.6.3 Heat sensitive materials are not to be used in the construction of valves and cocks.

11.6.4 Where drain cocks or valves are fitted to oil fuel tanks they are to be of the self-closing type and suitable provision is to be made for collecting the oil discharge.

11.7 Flexible hoses for oil fuel systems

11.7.1 Where necessary, flexible pipes of approved type may be used as short joining lengths to the engine.

11.8 Pipe joints for oil fuel systems

11.8.1 Where flanged joints are used the jointing material is to be impervious to oil. Cone type joints and approved types of compression fittings may be permitted for pipes having a bore not exceeding 40 mm.

11.8.2 Soft solder is not to be used for attaching pipe fittings.

11.9 Engine cooling system

11.9.1 Where sea water is used for the direct cooling of the engine, an efficient strainer which can be cleared from inside the craft is to be fitted between the sea inlet valve and the pump.

11.9.2 Means are to be provided for cleaning the strainer without interruption to the cooling water supply, where necessary.

11.9.3 Means are to be provided for indicating the temperature of the engine cooling media.

11.9.4 Alarms for the engine cooling water system are to be provided in accordance with Part 10.

11.10 Lubricating oil system

11.10.1 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be made for the efficient filtration of the oil.

11.10.2 Where necessary, flexible pipes of approved type may be used as short joining lengths to the engine.

11.10.3 In general, joints are to be of the flanged type with jointing materials which are impervious to oil. Cone type joints and approved types of compression fittings may be permitted for pipes having a bore not exceeding 40 mm.

11.10.4 Soft solder is not to be used for attaching pipe fittings.

11.10.5 Means are to be provided for indicating the lubricating oil pressure.

11.10.6 Alarms for the lubricating oil systems are to be provided in accordance with Part 10.

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter are applicable to fusion welded pressure vessels and their mountings and fittings, where plans have to be submitted in accordance with 1.2.

1.1.2 Seamless pressure vessels are to be manufactured in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) where applicable.

1.1.3 Steam raising plant and associated pressure vessels should be designed and constructed in accordance with Pt 5, Ch 10 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

1.2 Details to be submitted

1.2.1 Plans of pressure vessels are to be submitted in triplicate for consideration where all the conditions in (a) or (b) are satisfied:

(a) The vessel contains vapours or gases, e.g. air receivers, hydrophore or similar vessels and gaseous CO_2 vessels for fire-fighting, and
pV > 600
p > 1
V > 100
V = volume (litres) of gas or vapour space

(b) The vessel contains liquefied gases for fire-fighting, or flammable liquids, and
p > 7
V > 100
V = volume (litres)
p = design pressure (bar).

1.3 Materials

1.3.1 Materials used in the construction are to be manufactured and tested in accordance with the requirements of the Rules for Materials.

1.3.2 The specified minimum tensile strength of carbon and carbon-manganese steel plates, pipes, forgings and castings is to be within the following general limits:

(a) For seamless and Class 1 and Class 2/1 fusion welded pressure vessels:
340 to 520 N/mm^2.

(b) For Class 2/2 and Class 3 fusion welded pressure vessels:
340 to 430 N/mm^2.

1.3.3 Where it is proposed to use materials other than those specified in the Rules for Materials, details of the chemical compositions, heat treatment and mechanical properties are to be submitted for approval. In such cases, the values of the mechanical properties used for deriving the allowable stress are to be subject to agreement by Lloyd's Register (hereinafter referred to as 'LR').

1.4 Classification of fusion welded pressure vessels

1.4.1 Fusion welded pressure vessels are graded as Class 1 where the shell thickness exceeds 38 mm.

1.4.2 Fusion welded pressure vessels are graded as Class 2/1 and Class 2/2 if they comply with the following conditions:

(a) where the design pressure exceeds 17,2 bar, or
(b) where the metal temperature exceeds 150°C, or
(c) where the design pressure, in bar, multiplied by the actual thickness of the shell, in mm exceeds 157, or
(d) where the shell thickness does not exceed 38 mm.

1.4.3 For Rule purposes, Class 3 pressure vessels are to have a maximum shell thickness of 16 mm, and are pressure vessels not included in Classes 1, 2/1 or 2/2.

1.5 Design pressure

1.5.1 The design pressure is the maximum permissible working pressure and is to be not less than the highest set pressure of any safety valve.

1.6 Metal temperature

1.6.1 The metal temperature, T, used to evaluate the allowable stress, σ, is to be taken as the actual mean wall metal temperature expected under operating conditions for the pressure part concerned, and is to be stated by the manufacturer when plans of the pressure parts are submitted for consideration.

1.6.2 For fusion welded pressure vessels the minimum design temperature, T, is not to be less than 50°C.

1.7 Definition of symbols

1.7.1 The symbols used in the various formulae in Sections 2 to 6, unless otherwise stated, are defined as follows and are applicable to the specific part of the pressure vessel under consideration:

p = design pressure, in bar, *see* 1.5
r_i = inside knuckle radius, in mm
r_o = outside knuckle radius, in mm
t = minimum thickness, in mm
D_i = inside diameter, in mm
D_o = outside diameter, in mm
J = joint factor applicable to welded seams
R_i = inside radius, in mm
R_o = outside radius, in mm
T = design temperature, in °C
σ = allowable stress, in N/mm^2, *see* 1.8.

1.7.2 Where reference is made to calculated or actual plate thickness for the derivation of other values, these thicknesses are to be minus the standard Rule corrosion allowance of 0,75 mm, if not so stated.

1.8 Allowable stress

1.8.1 The term ‘allowable stress’, σ, is the stress to be used in the formulae for the calculation of scantlings of pressure parts.

1.8.2 The allowable stress, σ, is to be the lowest of the following values:

$$\sigma = \frac{E_t}{1,5}$$

$$\sigma = \frac{R_{20}}{2,7}$$

$$\sigma = \frac{S_R}{1,5}$$

where

E_t = specified minimum lower yield stress or 0,2 per cent proof stress at temperature, T, for carbon and carbon-manganese steels. In the case of austenitic steels, the 1,0 per cent proof stress at temperature, T, is to be used
R_{20} = specified minimum tensile strength at room temperature
S_R = average stress to produce rupture in 100 000 hours at temperature, T
T = metal temperature, *see* 1.6.

1.8.3 The allowable stress for steel castings is to be taken as 80 per cent of the value determined by the method indicated in 1.8.2, using the appropriate values for cast steel.

1.8.4 Where steels castings, which have been tested in accordance with Part 2, are also subjected to non-destructive tests, consideration will be given to increasing the allowable stress using a factor up to 90 per cent in lieu of the 80 per cent referred to in 1.8.3. Particulars of the non-destructive test proposals are to be submitted for consideration.

1.9 Joint factors

1.9.1 The following joint factors are to be used in the equations in Sections 2 to 6, where applicable. Fusion welded pressure parts are to be made in accordance with Section 8.

Class of pressure vessel	Joint factor
Class 1	1,0
Class 2/1	0,85
Class 2/2	0,75
Class 3	0,6

1.9.2 The longitudinal joints for all Classes of vessels are to be butt joints. Circumferential joints for Class 1 vessels and all classes of vessel for the production and storage of steam are also to be butt welds. Circumferential joints for Class 2/1, 2/2 and 3 vessels should also be butt joints with the following exceptions:

(a) Circumferential joints for Class 2/1, 2/2 and 3 vessels may be of the joggle type provided neither plate at the joints exceeds 16 mm thickness.
(b) Circumferential joints for Class 3 vessels may be of the lap type provided neither plate at the joint exceeds 16 mm thickness nor the internal diameter of the vessel exceeds 610 mm.

For typical acceptable methods of attaching dished ends, *see* Fig. 4.6.1.

1.10 Pressure parts of irregular shape

1.10.1 Where pressure parts are of such irregular shape that it is impracticable to design their scantlings by the application of formulae in this Chapter, the suitability of their construction is to be determined by hydraulic proof test of a prototype or by agreed alternative method.

Section 2 Cylindrical shells subject to internal pressure

2.1 Minimum thickness

2.1.1 Minimum thickness, t, of a cylindrical shell is to be determined by the following formula:

$$t = \frac{p\,R_i}{10\sigma J - 0{,}5p} + 0{,}75 \text{ mm}$$

where

t, p, R_i and σ are defined in 1.7

J = the joint factor of the longitudinal joints (expressed as a fraction), *see* 1.9.1. In the case of seamless shells clear of openings, J = 1,0.

2.1.2 The formula in 2.1.1 is applicable only where the resulting thickness does not exceed half the internal radius, i.e. where R_o is not greater than $1{,}5R_i$.

2.1.3 For fusion welded pressure vessels, t, is to be not less than $3 + \dfrac{D_i}{1500}$ mm,

where

D_i is as defined in 1.7.

2.1.4 The minimum thickness of vessels manufactured of corrosion resistant steels will be the subject of special consideration.

2.2 Unreinforced openings

2.2.1 The maximum diameter, d, of any unreinforced isolated openings is to be determined by the following formula:

$d = 8{,}08\,[D_o\,t\,(1 - K)]^{1/3}$ in mm

The value of K to be used is calculated from the following formula:

$$K = \frac{p\,D_o}{18{,}2\sigma t}$$ but is not to be taken as greater than 0,99

where

p, D_o and σ are as defined in 1.7

t = actual thickness of shell, in mm.

2.2.2 For elliptical or oval holes, d, for the purposes of 2.2.1, refers to the major axis when this lies longitudinally or to the mean of the major and minor axes when the minor axis lies longitudinally.

2.2.3 No unreinforced opening is to exceed 200 mm in diameter.

2.2.4 Holes may be considered isolated if the centre distance between two holes on the longitudinal axis of a cylindrical shell is not less than:

$d + 1{,}1\sqrt{D\,t}$ with a minimum $5d$

where

d = diameter of openings in shell (mean diameter if dissimilarly sized holes are involved)

D = mean diameter of shell

t = actual thickness of shell

Where the centre distance is less than so derived, the holes are to be fully compensated.

2.3 Reinforced openings

2.3.1 Openings larger than those permitted by 2.2 are to be compensated in accordance with Fig. 4.2.1(a) or (b). The following symbols are used in Fig. 4.2.1(a) and (b):

t_s = calculated thickness of a shell without joint or opening or corrosion allowance, in mm

t_d = thickness calculated in accordance with 3.1 without corrosion allowance, in mm

t_a = actual thickness of shell plate without corrosion allowance, in mm

t_b = actual thickness of standpipe without minus tolerances and corrosion allowance, in mm

t_r = thickness of added reinforcement, in mm

D_i = internal diameter of cylindrical shell, in mm

d_o = diameter of hole in shell, in mm

L = width of added reinforcement not exceeding D, in mm

$C = \sqrt{d_o\,t_b}$ in mm

$D = \sqrt{D_i\,t_a}$ and is not to exceed $0{,}5d_o$, in mm

σ = shell plate allowable stress, N/mm^2

σ_p = standpipe allowable stress, N/mm^2

σ_r = added reinforcement allowable stress, N/mm^2

σ_w = weld metal allowable stress, N/mm^2

NOTE

σ_p, σ_r and σ_w are not to be taken as greater than σ.

2.3.2 For elliptical or oval holes, the dimension on the meridian of the shell is to be used for d_o in 2.3.1.

2.3.3 The welds attaching standpipes and reinforcing plates to the shell are to be of sufficient size to transmit the full strength of the reinforcing areas and all other loadings to which they may be subjected.

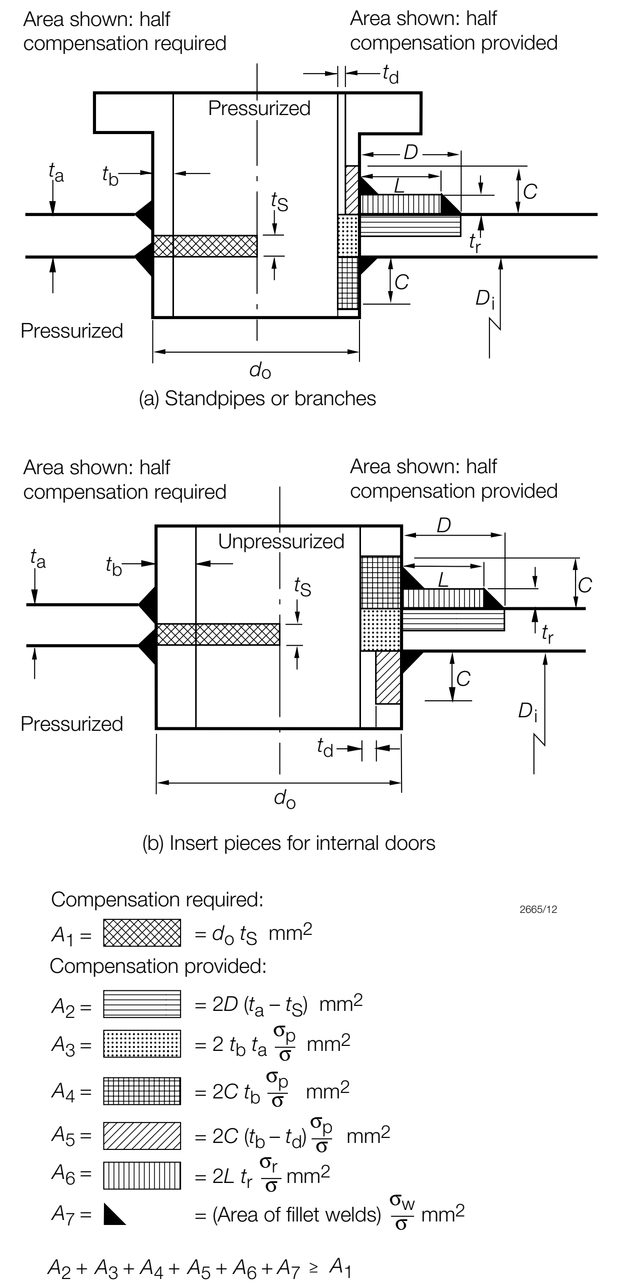


Fig. 4.2.1
Compensation for welded standpipes or branches in cylindrical shells

Section 3
Spherical shells subject to internal pressure

3.1 Minimum thickness

3.1.1 The minimum thickness, t, of a spherical shell is to be determined by the following formula:

$$t = \frac{p\,R_i}{20\sigma\,J - 0{,}5p} + 0{,}75 \text{ mm}$$

where

t, p, R_i, σ and J are as defined in 1.7.

3.1.2 The formula in 3.1.1 is applicable only where the resulting thickness does not exceed half the internal radius.

3.1.3 Irrespective of the thickness determined by the formula in 3.1.1, t is to be not less than $\frac{D_i}{1500}$ + 3 mm for other pressure vessels, where D_i is as defined in 1.7.

3.1.4 The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

3.1.5 Openings in spherical shells requiring compensation are to comply, in general, with 2.3, using the calculated and actual thicknesses of the spherical shell as applicable.

Section 4
Dished ends subject to internal pressure

4.1 Minimum thickness

4.1.1 The thickness, t, of semi-ellipsoidal and hemispherical unstayed ends, and the knuckle section of torispherical ends, dished from plate, having pressure on the concave side and satisfying the conditions listed below, is to be determined by the following formula:

$$t = \frac{p\,D_o\,K}{20\sigma\,J} + 0{,}75 \text{ mm}$$

where

t, p, D_o, σ and J are as defined in 1.7

K = a shape factor, *see* 4.2 and Fig. 4.4.1.

4.1.2 For semi-ellipsoidal ends:

the external height, $H \geq 0{,}18D_o$

where

D_o = the external diameter of the parallel portion of the end, in mm.

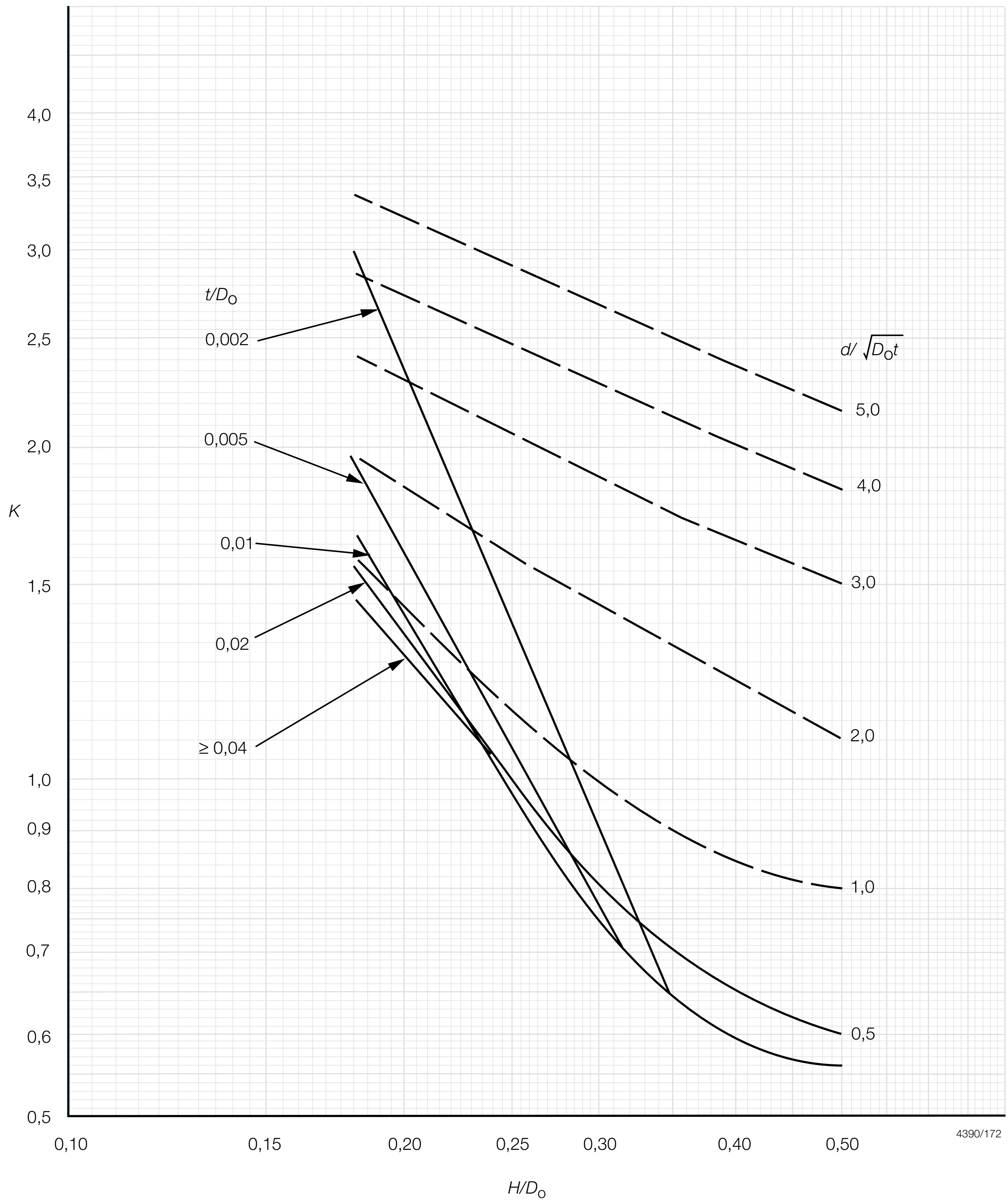


Fig. 4.4.1 Shape factor

4.1.3 For torispherical ends:

- the internal radius, $R_i \le D_o$
- the internal knuckle radius, $r_i \ge 0{,}1D_o$
- the internal knuckle radius, $r_i \ge 3t$
- the external height, $H \ge 0{,}18D_o$ and is determined as follows:

$$H = R_o - \sqrt{(R_o - 0{,}5D_o)(R_o + 0{,}5D_o - 2r_o)}$$

4.1.4 In addition to the formula in 4.1.1 the thickness, t, of a torispherical head, made from more than one plate, in the crown section is to be not less than that determined by the following formula:

$$t = \frac{p\,R_i}{20\sigma J - 0{,}5p} + 0{,}75 \text{ mm}$$

where

t, p, R_i, σ and J are as defined in 1.7.

4.1.5 The thickness required by 4.1.1 for the knuckle section of a torispherical head is to extend past the common tangent point of the knuckle and crown radii into the crown section for a distance not less than $0{,}5\sqrt{R_i\,t}$ mm, before reducing to the crown thickness permitted by 4.1.4,

where

t = the required thickness from 4.1.1.

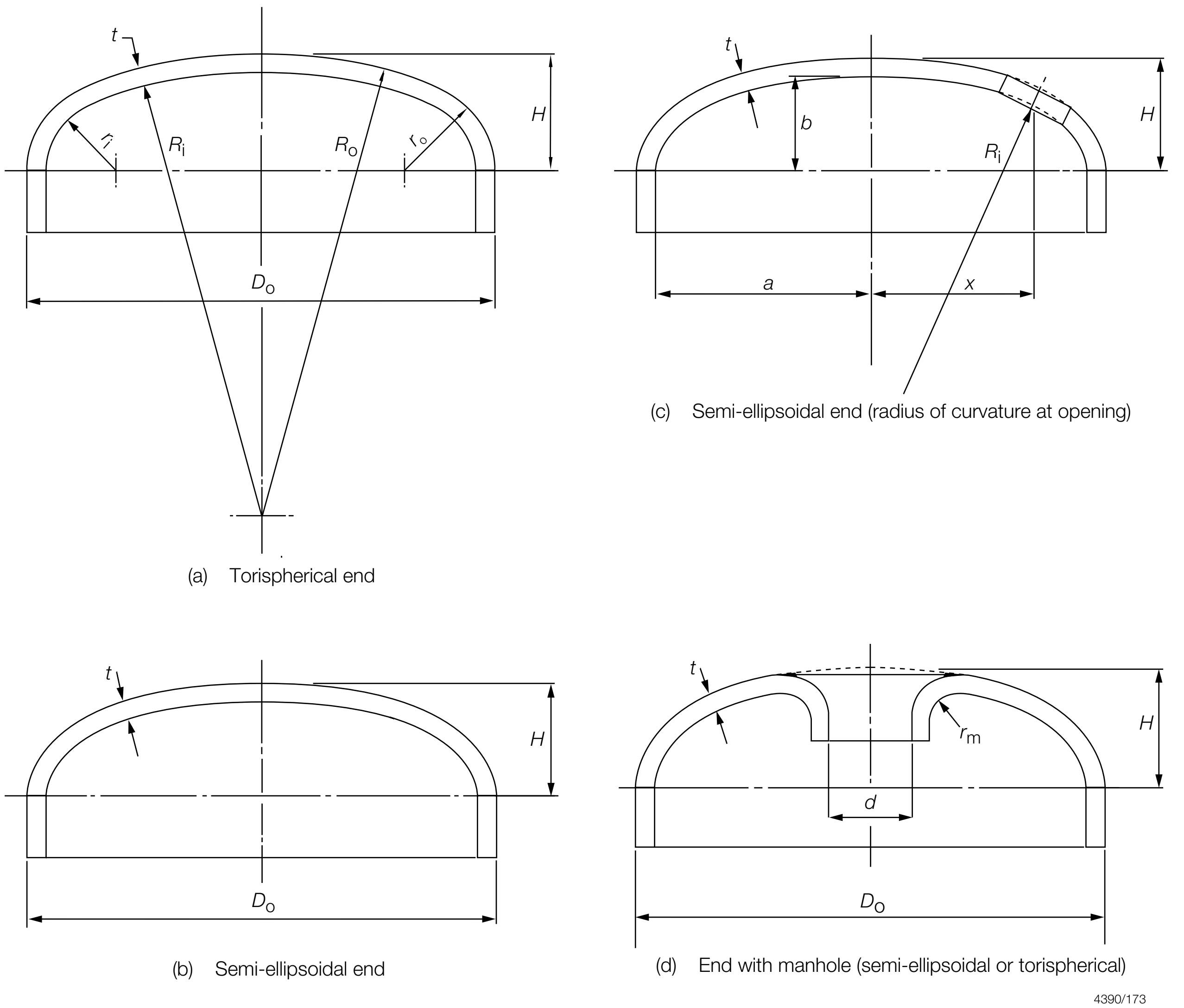
4.1.6 In all cases, H, is to be measured from the commencement of curvature, *see* Fig. 4.4.2.

4.1.7 For fusion welded pressure vessels the minimum thickness of the head, t, is to be not less than $3 + \frac{D_i}{1500}$ mm

where

D_i is as defined in 1.7.

4.1.8 For ends which are butt welded to the shell the thickness of the edge of the flange for connection to the shell is to be not less than the thickness of an unpierced seamless or welded shell, whichever is applicable, of the same diameter and material and determined by 2.1.



(a) Torispherical end

(c) Semi-ellipsoidal end (radius of curvature at opening)

(b) Semi-ellipsoidal end

(d) End with manhole (semi-ellipsoidal or torispherical)

Fig. 4.4.2 Typical dished ends

4.2 Shape factors for dished ends

4.2.1 The shape factor, K, to be used in 4.1.1 is to be obtained from the curves in Fig. 4.4.1, and depends on the ratio of height to diameter $\frac{H}{D_o}$.

4.2.2 The lowest curve in the series provides the factor, K, for plain (i.e. unpierced) ends. For lower values of $\frac{H}{D_o}$, K depends upon the ratio of thickness to diameter, $\frac{t}{D_o}$, as well as on the ratio $\frac{H}{D_o}$, and a trial calculation may be necessary to arrive at the correct value of K.

4.3 Dished ends with unreinforced openings

4.3.1 Openings in dished ends may be circular, obround or approximately elliptical.

4.3.2 The upper curves in Fig. 4.4.1 provide values of K, to be used in 4.1.1, for ends with unreinforced openings. The selection of the correct curve depends on the value of $\frac{d}{\sqrt{D_o\, t}}$ and a trial calculation is necessary to select the correct curve,
where

d = the diameter of the largest opening in the end plate, in mm (in the case of an elliptical opening, the larger axis of the ellipse)
t = minimum thickness, after dishing, in mm
D_o = outside diameter of dished end, in mm.

4.3.3 The following requirements must in any case be satisfied:

$$\frac{t}{D_o} \leq 0{,}1$$

$$\frac{d}{D_o} \leq 0{,}7$$

4.3.4 From Fig. 4.4.1 for any selected ratio of $\frac{H}{D_o}$ the curve for unpierced ends gives a value for $\frac{d}{\sqrt{D_o\, t}}$ as well as for K. Openings giving a value of $\frac{d}{\sqrt{D_o\, t}}$ not greater than the value so obtained may thus be pierced through an end designed as unpierced without any increase in thickness.

4.4 Flanged openings in dished ends

4.4.1 The requirements in 4.3 apply equally to flanged openings and to unflanged openings cut in the plate of an end. No reduction may be made in end plate thickness on account of flanging.

4.4.2 Where openings are flanged, the radius, r_m of the flanging is to be not less than 25 mm, *see* Fig. 4.4.2(d). The thickness of the flanged portion may be less than the calculated thickness.

4.5 Location of unreinforced and flanged openings in dished ends

4.5.1 Unreinforced and flanged openings in dished ends are to be so arranged that the distance from the edge of the hole to the outside edge of the plate and the distance between openings are not less than those shown in Fig. 4.4.3.

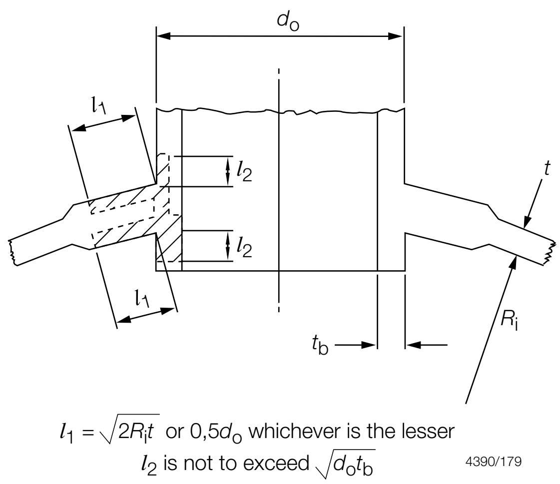


Fig. 4.4.3 Limits for reinforcement

4.6 Dished ends with reinforced openings

4.6.1 Where it is desired to use a large opening in a dished end of less thickness than would be required by 4.3, the end is to be reinforced. This reinforcement may consist of a ring or standpipe welded into the hole, or of reinforcing plates welded to the outside and/or inside of the end in the vicinity of the hole, or a combination of both methods, *see* Fig. 4.4.4. Forged reinforcements may be used.

4.6.2 Reinforcing material with the following limits may be taken as effective reinforcement:

(a) The effective width, l_1 of reinforcement is not to exceed $\sqrt{2R_i\, t}$ or 0,5d_o whichever is the lesser.

(b) The effective length, l_2 of a reinforcing ring is not to exceed $\sqrt{d_o\, t_b}$

where

R_i = the internal radius of the spherical part of a torispherical end, in mm, or

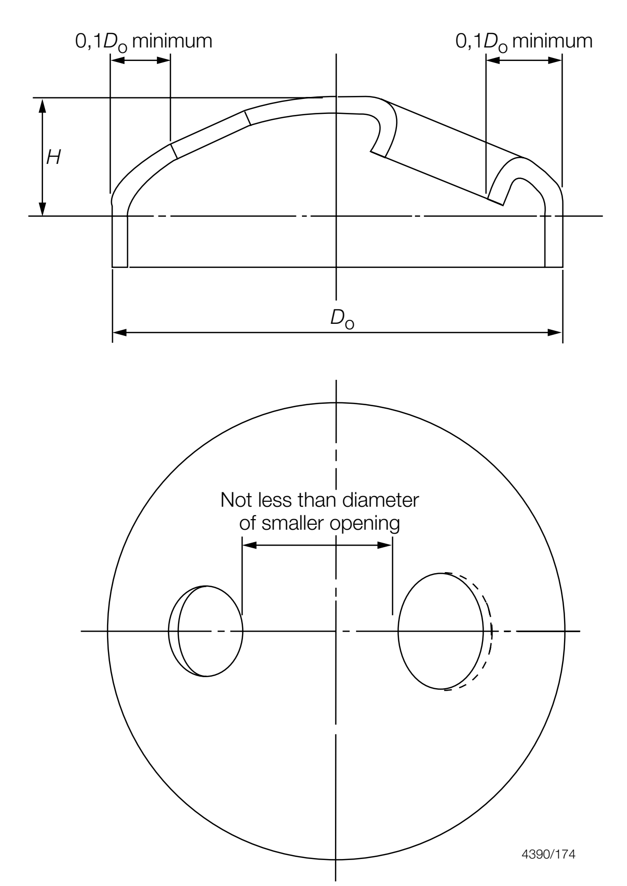


Fig. 4.4.4 Opening in dished ends

R_i = internal radius of the meridian of the ellipse at the centre of the opening, of a semi-ellipsoidal end, in mm, and is given by the following formula:

$$\frac{\left[a^4 - x^2\left(a^2 - b^2\right)\right]^{3/2}}{a^4\, b}$$

where

a, b and x are shown in Fig. 4.4.2(c)

d_o = external diameter of ring or standpipe, in mm

l_1 and l_2 are shown in Fig. 4.4.3

t_b = actual thickness of ring or standpipe, in mm.

4.6.3 The shape factor, K, for a dished end having a reinforced opening can be read from Fig. 4.4.1 using the value obtained from:

$$\frac{d_o - \dfrac{A}{t}}{\sqrt{D_o\, t}} \text{ instead of from } \frac{d}{\sqrt{D_o\, t}}$$

where

A = the effective cross-sectional area of reinforcement and is to be twice the area shown shaded on Fig. 4.4.3

As in 4.3, a trial calculation is necessary in order to select the correct curve.

4.6.4 The area shown in Fig. 4.4.3 is to be obtained as follows:

- Calculate the cross-sectional area of reinforcement both inside and outside the end plate within the length, l_1, plus the full cross-sectional area of that part of the ring or standpipe which projects inside the end plate up to a distance, l_2, plus the full cross-sectional area of that part of the ring or standpipe which projects outside the internal surface of the end plate up to a distance, l_2, and deduct the sectional area which the ring or standpipe would have if its thickness were as calculated in accordance with 5.1.

4.6.5 If the material of the ring or the reinforcing plates has an allowable stress value lower than that of the end plate, then the effective cross-sectional area, A, is to be multiplied by the ratio:

$$\frac{\text{allowable stress of reinforcing plate at design temperature}}{\text{allowable stress of end plate at design temperature}}$$

4.7 Torispherical dished ends with reinforced openings

4.7.1 If an opening and its reinforcement are positioned entirely within the crown section, the compensation requirements are to be as for a spherical shell, using the crown radius as the spherical shell radius. Otherwise, the requirements of 4.6 are to be applied.

■ *Section 5* Standpipes and branches

5.1 Minimum thickness

5.1.1 The minimum wall thickness, t, of standpipes and branches is to be not less than the greater of the two values determined by the following formulae, making such additions as may be necessary on account of bending, static loads and vibrations:

$$t = \frac{p\, D_o}{20\sigma + p} + 0{,}75 \text{ mm}$$

$$t = 0{,}04 D_o + 2{,}5 \text{ mm}$$

where

t, p, D_o and σ are defined in 1.7.

If the second formula applies, the thickness need only be maintained for a length, L, from the outside surface of the vessel, but need not extend past the first connection, butt weld or flange, where:

$$L = 3{,}5\sqrt{D_o\, t} \text{ mm}$$

5.1.2 In no case does the wall thickness need to exceed that of the shell as required by 2.1, 3.1 or 4.1 as applicable.

Section 6
Unstayed circular flat end plates

6.1 Minimum thickness

6.1.1 Ends attached by welding are to be designed such that the minimum thickness of flat end plates is to be determined by the following formula:

$$t = d_i \sqrt{\frac{pC}{\sigma}} + 0{,}75 \text{ mm}$$

where

p and σ are as defined in 1.7.

t = minimum thickness of end plate, in mm

d_i = internal diameter of circular shell, in mm

C = a constant depending on method of end attachment, *see* Fig. 4.6.1

(a) For end plates welded as shown in Fig. 4.6.1(a):

C = 0,019 for circular shells.

(b) For end plates welded as shown in Figs. 4.6.1(b) and (c):

C = 0,028 for circular shells.

6.1.2 Where flat end plates are bolted to flanges attached to the ends of headers, the flanges and end plates are to be in accordance with recognized pipe flange standards.

6.1.3 Openings in flat plates are to be compensated in accordance with Fig. 4.2.1(a) or (b) with the value of A_1, the compensation required, calculated as follows:

$$A_1 = \frac{d_o}{2{,}4} t_f \text{ mm}^2$$

where

d_o = diameter of hole in flat plate, in mm

t_f = required thickness of the flat plate in the area under consideration, in mm, calculated in accordance with 6.1.1, as applicable, without corrosion allowance

Limit D = $0{,}5d_o$.

Section 7
Construction

7.1 Access arrangements

7.1.1 Pressure vessels are to be so made that the internal surfaces may be examined. Wherever practicable, the openings for this purpose are to be sufficiently large for access and for cleaning the inner surfaces.

7.1.2 Manholes in cylindrical shells should preferably have their shorter axes arranged longitudinally.

7.1.3 Doors for manholes and sightholes are to be formed from the steel plate or of other approved construction, and all jointing surfaces are to be machined.

7.1.4 Doors of the internal type are to be provided with spigots which have a clearance of not more than 1,5 mm all round, i.e. the axes of opening are not to exceed those of the door by more than 3 mm. The width of the manhole gasket seat is not to be less than 16 mm.

7.1.5 Doors of the internal type for openings not larger than 230 x 180 mm need be fitted with only one stud, which may be forged integral with the door. Doors for openings larger than 230 mm x 180 mm are to be fitted with two studs or bolts. The strength of the attachment to the door is not to be less than the strength of the stud or bolt.

7.1.6 The crossbars or dogs for doors are to be of steel.

7.1.7 External circular flat cover plates are to be in accordance with a recognized standard.

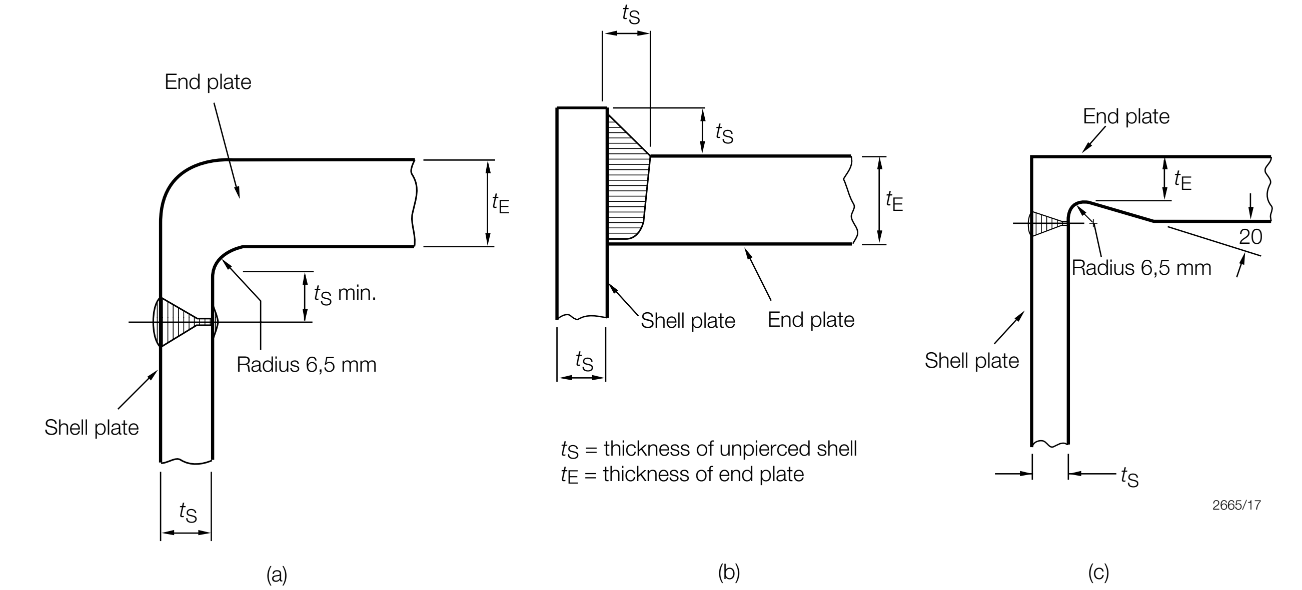


Fig. 4.6.1 Typical methods of attachment of unstayed circular flat end plates

7.2 Torispherical and semi-ellipsoidal ends

7.2.1 For typically acceptable types of attachment for dished ends to cylindrical shells, *see* Fig. 4.7.1. Types (d) and (e) are to be made a tight fit in the cylindrical shell.

7.2.2 Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

7.2.3 The thickness of the plates at the position of the circumferential weld is to be not less than that of an unpierced cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material, *see* 2.1.

7.3 Welded-on flanges, butt welded joints and fabricated branch pieces

7.3.1 Flanges may be cut from plates or may be forged or cast. Hubbed flanges are not to be machined from plate. Flanges are to be attached to branches by welding. Alternative methods of flange attachment will be subject to special consideration.

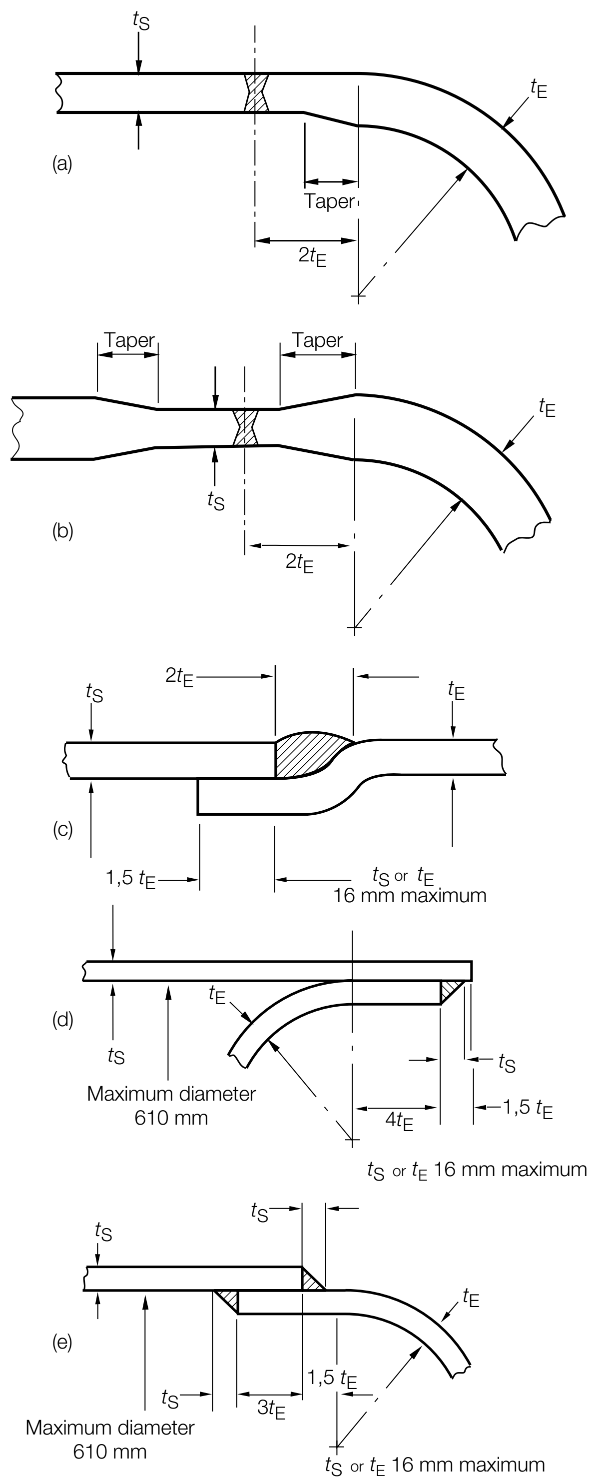
7.3.2 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the branches are intended.

7.3.3 Flange attachments and pressure-temperature ratings in accordance with materials and design of recognized standards will be accepted.

7.3.4 Typical examples of welded-on flange connections are shown in Fig. 4.7.2(a) to (f), and limiting design conditions for the flange types are shown in Table 4.7.1. In Fig. 4.7.2, *t* is the minimum Rule thickness of the standpipe or branch.

7.3.5 Welded-on flanges are not to be a tight fit on the branch. The maximum clearance between the bore of the flange and the outside diameter of the branch is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

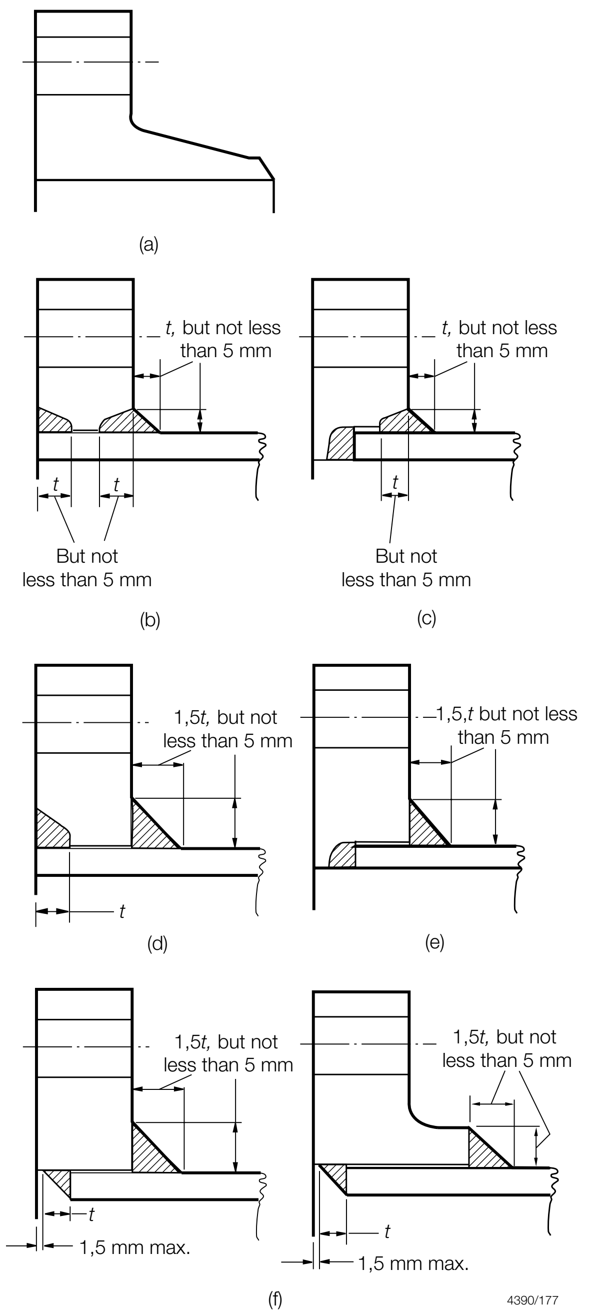
7.3.6 Where butt welds are employed in the attachment of flange type (a), or in the construction of standpipes or branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to that of the thinner at the butt joint.



Type of end attachment	Acceptable for
(a) and (b)	All classes
(c)	2/1, 2/2 and 3
(d) and (e)	Class 3 only

4390/176

Fig. 4.7.1
Typical attachment of dished ends to cylindrical shell



'*t*' is the minimum Rule thickness of standpipe or branch

Fig. 4.7.2
Typical example of welded flange connections

7.3.7 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but in general, oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to branches exceeding 100 mm diameter or 9,5 mm thick.

7.3.8 Threaded sleeve joints complying with Ch 1,5.5.1 may be used on the steam and water piping of small oil fired package boilers of the once through coil type, used for auxiliary or domestic purposes, where the feed pump capacity limits the output.

7.3.9 Socket weld joints are not to be used where fatigue, severe erosion, crevice corrosion or stress corrosion are expected to occur, for example, blow down, drain, scum and chemical dosing connections.

7.4 Welded attachments to pressure vessels

7.4.1 Unless the actual thickness of the shell or end is at least twice that required by calculation for a seamless shell or end, whichever is applicable, doubling plates with well rounded corners are to be fitted in way of attachments such as lifting lugs, supporting brackets and feet, to minimize load concentrations on pressure shells and ends. Compensating plates, pads, brackets and supporting feet are to be bedded closely to the surface before being welded, and are to be provided with a 'tell-tale' hole not greater than 9,5 mm in diameter, open to the atmosphere to provide for the release of entrapped air during heat treatment of the vessel, or as a means of indicating any leakage during hydraulic testing and in service.

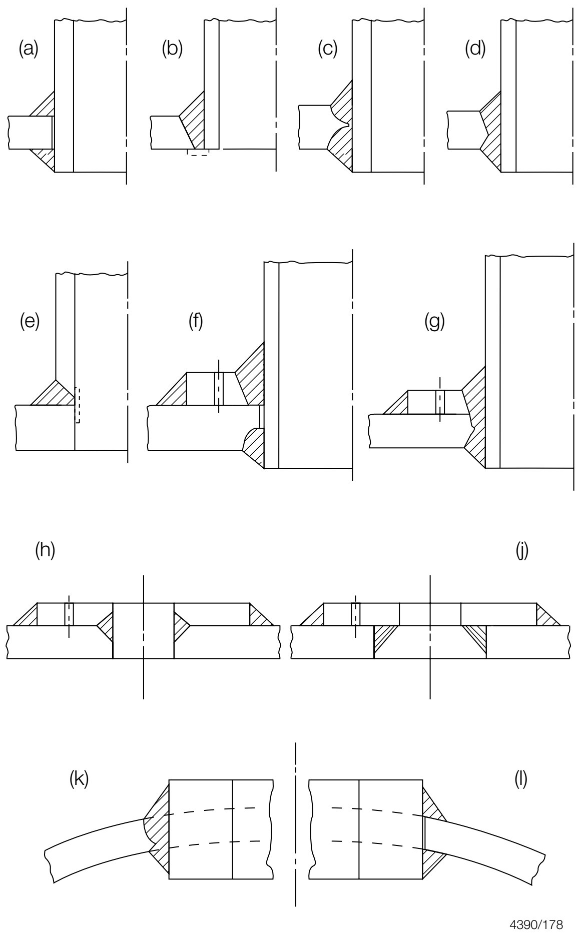
7.4.2 For acceptable methods of attaching standpipes, branches, compensating plates and pads, *see* Fig. 4.7.3. Alternative methods of attachment may be accepted provided details are submitted for consideration.

7.4.3 Where fillet welds are used to attach standpipes, there are to be equal sized welds both inside and outside the vessel shell, *see* Fig. 4.7.3(a) and (l). The leg length of each of the fillet welds is to be not less than the actual thickness of the thinner of the parts being joined.

Table 4.7.1 Limiting design conditions for flanges

Flange type	Maximum pressure	Maximum temperature	Maximum pipe o.d.	Minimum pipe bore
		°C	mm	mm
(a)	Pressure temperature ratings to be in accordance with a recognized standard	No restriction	No restriction	No restriction
(b)		No restriction	168,3 for alloy steels*	No restriction
(c)		No restriction	168,3 for alloy steels*	75
(d)		425	No restriction	No restriction
(e)		425	No restriction	75
(f)		425	No restriction	No restriction

NOTE
* No restriction for carbon steels



Type (a) and (l) attachments are not to be used for openings which require to be compensated. Backing rings may be used with types (b) and (e).

Fig. 4.7.3
Typical acceptable methods of attaching branches and pads

Section 8
Requirements for fusion welded pressure vessels

8.1 Class 1 and Class 2/1

8.1.1 Fusion welded pressure vessels constructed to Class 1 and Class 2/1 requirements will be accepted only if manufactured by firms equipped and competent to undertake high quality welding. In order that firms may be approved for this purpose, it will be necessary for the Surveyors to visit the works for the purpose of inspecting the welding plant equipment and procedures, and to arrange for the carrying out of preliminary tests as stated in Pt 5, Ch 17,3 of the Rules for Ships.

8.1.2 The welding plant and equipment are to be suitable for undertaking work of the standards required for Class 1 and Class 2/1 welding.

8.1.3 The works are to have an efficient testing laboratory, suitably equipped to carry out tensile, bend and impact tests, the X-ray examination of pressure vessels, and the metallographic examination of welds. The works are also to be equipped with a suitable heat treating furnace with satisfactory means of temperature control.

8.1.4 Alternative arrangements which, in the opinion of the Surveyors, ensure an equally high standard of quality control may be submitted for consideration.

8.1.5 On completion of the inspection and tests, the Surveyor's report, including the results of the preliminary tests is to be submitted for consideration. The report should also include the radiographs and particulars of any fusion welded pressure vessels previously constructed at these works.

8.2 Class 2/2

8.2.1 Pressure vessels made in accordance with Class 2/2 requirements will be accepted only if constructed by firms whose works are properly equipped to undertake the welding of pressure vessels of this Class.

8.2.2 It will be necessary for the Surveyors to visit the works for the purpose of inspecting the welding plant, equipment and procedures, and to arrange for the carrying out of preliminary tests as stated in 8.1.

8.2.3 On completion of the inspection and tests, the Surveyor's report, together with the results of the preliminary tests and particulars of fusion welded pressure vessels previously constructed at these works, is to be submitted for the consideration of the Committee.

8.3 Class 3

8.3.1 Class 3 pressure vessels will be accepted if constructed by firms whose works are equipped to undertake the welding of pressure vessels of this Class.

8.3.2 It will be necessary for the Surveyors to visit the works for the purpose of inspecting the welding plant, equipment and procedures, and to arrange for the carrying out of preliminary tests as stated in 7.1.

■ *Section 9* Mountings and fittings for pressure vessels

9.1 General

9.1.1 Each pressure vessel or system is to be fitted with a stop valve situated as close as possible to the shell.

9.1.2 Adequate arrangements are to be provided to prevent over-pressure of any part of a pressure vessel which can be isolated. Pressure gauges are to be fitted in positions where they can be easily read.

9.1.3 Adequate arrangements are to be provided for draining and venting the separate parts of each pressure vessel.

9.2 Receivers containing pressurized gases

9.2.1 Each air receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

9.2.2 Each receiver which can be isolated from a relief valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C. *See also* 9.2.3 and 9.2.4.

9.2.3 Where a fixed system utilizing fire-extinguishing gas is fitted, to protect a machinery space containing an air receiver(s), fitted with a fusible plug, it is recommended that the discharge from the fusible plug be piped to the open deck.

9.2.4 Receivers used for the storage of air for the control of remotely operated valves are to be fitted with relief valves and not fusible plugs.

■ *Section 10* Hydraulic tests

10.1 Fusion welded pressure vessels

10.1.1 Fusion welded pressure vessels are to be tested on completion to a pressure, p_T, determined by the following formula, without showing signs of weakness or defect:

$$p_T = 1{,}3 \frac{\sigma_{50}}{\sigma_t} \frac{t}{(t - 0{,}75)} p$$

but in no case is to exceed

$$1{,}5 \frac{t}{(t - 0{,}75)} p$$

where

p = design pressure, in bar
p_T = test pressure, in bar
t = nominal thickness of shell as indicated on the plan, in mm
σ_T = allowable stress at design temperature, in N/mm^2
σ_{50} = allowable stress at 50°C, in N/mm^2.

10.2 Mountings

10.2.1 Mountings are to be subjected to a hydraulic test of twice the approved design pressure.

■ *Section 11* Fibre reinforced plastics pressure vessels

11.1 General

11.1.1 Pressure vessels may be constructed in fibre reinforced plastics provided the manufacturer is competent and suitably equipped for this purpose.

11.1.2 Pressure vessels are to be of standard design whose suitability has been established by fatigue and burst tests on a prototype.

11.2 Prototype testing

11.2.1 For the fatigue test the pressure shall be cycled from atmospheric to design pressure 100 000 times at the design temperature.

11.2.2 For the burst test the minimum bursting pressure shall be six times the design pressure.

11.3 Production hydraulic test

11.3.1 Vessels subject to internal pressure shall be hydraulically tested to not less than 1,5 times the design pressure.

■ *Section 12*
Requirements for craft which are not required to comply with the HSC Code

12.1 Fibre reinforced plastics pressure vessels

12.1.1 Fibre reinforced plastics pressure vessels, where the product of the design pressure in bar and volume in litres exceeds 600, are not to be situated in machinery spaces or high risk areas on yachts and service craft less than 24 m.

12.1.2 Small fibre reinforced plastics pressure vessels will receive special consideration in relation to their intended duty and service conditions.

RULES AND REGULATIONS FOR THE CLASSIFICATION OF SPECIAL SERVICE CRAFT

CONTROL AND ELECTRICAL ENGINEERING

JULY 2008

VOLUME 7

PART 16

Lloyd's Register

Chapter Contents

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■ *Section 1* General requirements

1.1 General

1.1.1 This Chapter applies to control engineering systems on special service craft.

1.1.2 Section 2 states requirements for alarm systems, safety systems and automatic or remote controls where fitted.

1.1.3 Section 3 states requirements which shall apply where it is intended to operate the craft with machinery spaces unattended. In general, craft complying with the requirements of Section 3 will be eligible for the class notation **UMS**.

1.1.4 Section 4 states requirements which shall apply where it is intended to operate the craft with machinery spaces under continuous supervision from a centralized control station. In general, craft complying with the requirements of Section 4 will be eligible for the class notation **CCS**.

1.1.5 Lloyd's Register (hereinafter referred to as 'LR') will be prepared to give consideration to special cases or to arrangements which are equivalent to the Rules.

1.2 Plans and information

1.2.1 Plans and information as detailed in 1.2.2 to 1.2.7 are to be submitted in triplicate.

1.2.2 A description of operation with explanatory diagrams together with line diagrams of control circuits, list of monitored, control and alarm points is required for the following machinery or equipment:

- Fixed water-based local application fire-fighting systems, *see* 2.9.
- Air compressors.
- Bilge systems.
- Controllable pitch propellers.
- Electric generating plant.
- Oil fuel transfer and storage systems.
- Propulsion machinery including essential auxiliaries.
- Steam raising plant (boilers and their ancillary equipment).
- Steering systems.
- Thermal fluid heaters.
- Thrust units.
- Valve position indicating systems.
- Waterjets for propulsion purposes.

1.2.3 **Test schedules** (for both works testing and sea trials), which should include methods of testing and test facilities, *see* 6.4.1.

1.2.4 **Alarm systems**. Details of the overall alarm system linking the main control station, subsidiary control stations, the bridge area and accommodation.

1.2.5 **Programmable electronic systems**.
(In addition to the documentation required by 1.2.2)

- System requirements specification.
- System integration plan, *see* 2.13.2.
- Failure Mode and Effects Analysis (FMEA), *see* 2.13.5.
- Details of the hardware configuration in the form of a system block diagram, including input/output schedules.
- Hardware certification details, *see* 2.10.5 and 2.12.3.
- Software quality plans, including applicable procedures, *see* 2.10.21.
- Factory acceptance, integration and sea trial test schedules for hardware and software.

1.2.6 **Control station**. Location and details of control stations, e.g. control panels and consoles.

1.2.7 **Fire detection systems**. Plans showing the system operation and the type and location of all machinery space fire detector heads, manual call points and the fire detector indicator panel(s). The plans are to indicate the position of the fire detectors in relation to significant items of machinery, ventilation and extraction openings.

1.2.8 **Approved system**. Where it is intended to employ a standard system which has been previously approved, plans are not required to be submitted, providing there have been no changes in the applicable Rule requirements. Details of the previous approval are to be submitted.

1.2.9 **Cables**. For details of instrumentation and control system cabling requirements, *see* Ch 2,10.

1.3 Control, alarm and safety equipment

1.3.1 Major units of equipment associated with control, alarm and safety systems as defined in 1.2 are to be surveyed at the manufacturers' works and the inspection and testing is to be to the Surveyor's satisfaction, *see also* 1.2.2.

1.3.2 Equipment used in control, alarm and safety systems is to be suitable for its intended purpose, and accordingly, whenever practicable, be selected from the *List of Lloyd's Register Type Approved Products* published by LR.

1.3.3 Where equipment requires a controlled environment, an alternative means is to be provided to maintain the required environment in the event of a failure of the normal air conditioning system. Failure of the air conditioning system is to initiate an alarm.

1.3.4 Assessment of performance parameters, such as accuracy, repeatability, etc., are to be in accordance with an acceptable National or International Standard, e.g. IEC 60051, *Direct acting indicating analogue electrical measuring instruments and their accessories*.

1.4 Alterations and additions

1.4.1 When an alteration or addition to the approved system(s) is proposed, plans are to be submitted for approval. The alterations or additions are to be carried out under survey and the installation and testing are to be to the Surveyor's satisfaction.

1.4.2 Details of proposed software modifications are to be submitted for consideration. Where the modification may affect compliance with these Rules, proposals for verification and validation are also to be submitted.

1.4.3 Software versions are to be uniquely identified by number, date or other appropriate means. Modifications are not to be made without also changing the version identifier. A record of changes to the system since the original issue (and their identification) is to be maintained and made available to the LR Surveyor on request.

■ *Section 2*
Essential features for control, alarm and safety systems

2.1 General

2.1.1 Where it is proposed to install control, alarm and safety systems to the equipment listed in 1.2.2 the applicable features contained in this Section are to be incorporated in the system design.

2.1.2 Systems complying with ISO 17894, *Ships and marine technology - Computer applications - General principles for the development and use of programmable electronic systems in marine applications*, may be accepted as meeting the requirements of this Section in which case evidence of compliance is to be submitted for consideration.

2.2 Control stations for machinery

2.2.1 A system of alarm displays and controls is to be provided which readily ensures identification of faults in the machinery and satisfactory supervision of related equipment. This may be provided at a main control station or, alternatively at subsidiary control stations. In the latter case, a master alarm display is to be provided at the main control station showing which of the subsidiary control stations is indicating a fault condition.

2.2.2 At the main control station (if provided) or close to the subsidiary stations (if fitted) means of two way voice communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery spaces are to be provided.

2.2.3 Provision is to be made at the main control station, or subsidiary control stations as appropriate, for the operation of an engineers' alarm which is to be clearly audible in the engineers' accommodation.

2.2.4 Provision is to be made at the main control station and any other subsidiary control station from which the main propulsion and auxiliary machinery or associated equipment may be controlled to indicate which station is in control.

2.2.5 Control of machinery and associated equipment is to be possible only from one station at a time.

2.2.6 Changeover between control stations is to be arranged so that it may only be effected with the acceptance of the station taking control. The system is to be provided with interlocks or other suitable means to ensure effective transfer of control.

2.2.7 For additional requirements where control stations incorporate visual display units and keyboard input facilities, *see* 2.10.

2.3 Alarm systems

2.3.1 Where an alarm system, which will provide warning of faults in the machinery and the safety and control systems, is to be installed, the requirements of 2.3.2 to 2.3.18 are to be satisfied.

2.3.2 Machinery, safety and control system faults are to be indicated at the relevant control stations to advise duty personnel of a fault condition. The presence of unrectified faults is to be clearly indicated at all times.

2.3.3 Alarms associated with machinery, safety and control system faults are to be clearly distinguishable from other alarms e.g. fire, general alarm.

2.3.4 Where alarms are displayed as group alarms, provision is to be made to identify individual alarms at the main control station (if fitted) or alternatively at subsidiary control stations.

2.3.5 All alarms are to be both audible and visual. If arrangements are made to silence audible alarms they are not to extinguish visual alarms.

2.3.6 Acknowledgement of visual alarms is to be clearly indicated.

2.3.7 Acknowledgement of alarms at positions outside a machinery space is not to silence the audible alarm or extinguish the visual alarm in that machinery space.

2.3.8 If an alarm has been acknowledged and a second fault occurs prior to the first being rectified, audible and visual alarms are again to operate. Where alarms are displayed at a local panel adjacent to the machinery and with arrangements to provide a group or common fault alarm at the main control room alarm display then the occurrence of a second fault prior to the first alarm being rectified need only be displayed at the local panel, however the group alarm is to be reinitiated. Unacknowledged alarms on monitors are to be distinguished by either flashing text or a flashing marker adjacent to the text. A change of colour will not in itself be sufficient to distinguish between acknowledged and unacknowledged alarms.

2.3.9 For the detection of transient faults which are subsequently self-correcting, alarms are required to lock in until accepted.

2.3.10 The alarm system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply. Where an alarm system could be adversely affected by an interruption in power supply, changeover to the standby power supply is to be achieved without a break.

2.3.11 Failure of any power supply to the alarm system is to operate an audible and visual alarm.

2.3.12 The alarm system should be designed with self-monitoring properties. Insofar as practicable, any fault in the alarm system should cause it to fail to the alarm condition.

2.3.13 The alarm system is to be capable of being tested during normal machinery operation, *see* 6.1.2.

2.3.14 The alarm system is to be designed as far as practicable to function independently of control and safety systems such that a failure or malfunction in these systems will not prevent the alarm system from operating.

2.3.15 Disconnection or manual overriding of any part of the alarm system should be clearly indicated.

2.3.16 When alarm systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

2.3.17 Where monitors are provided at the station in control and, if fitted, in the duty engineer's accommodation, they are to provide immediate display of new alarm information regardless of the information display page currently selected. This may be achieved by provision of a dedicated alarm monitor, a dedicated area of screen for alarms or other suitable means.

2.3.18 Alarms are to be displayed in the order in which they occur. Alarms requiring shutdown or slowdown action are to be given visual prominence.

2.4 Safety systems

2.4.1 Where safety systems are provided, the requirements of 2.4.2 to 2.4.12 are to be satisfied.

2.4.2 Safety systems are to operate automatically in case of serious faults endangering the machinery, so that:

(a) normal operating conditions are restored, e.g. by the starting of standby machinery, or
(b) the operation of the machinery is temporarily adjusted to the prevailing conditions, e.g. by reducing the output of the machinery, or
(c) the machinery is protected from critical conditions by shutting off the fuel or power supplies thereby stopping the machinery.

2.4.3 The safety system required by 2.4.2(c) is to be designed as far as practicable to operate independently of the control and alarm systems, such that a failure or malfunction in the control and alarm systems will not prevent the safety system from operating.

2.4.4 For safety systems required by 2.4.2(a) and (b) complete independence from other control systems is not necessary.

2.4.5 Safety systems for different items of the machinery plant are to be arranged so that failure of the safety system of one part of the plant will not interfere with the operation of the safety system in another part of the plant.

2.4.6 The safety system is to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the safety system and its associated machinery, but also the complete installation.

2.4.7 When a safety system is activated, an audible and visual alarm is to be provided to indicate the cause of the safety action.

2.4.8 The safety system is to be manually reset before the relevant machinery can be restarted.

2.4.9 Where arrangements are provided for overriding a safety system, they are to be such that inadvertent operation is prevented. Visual indication is to be given at the relevant control station(s) when a safety override is operated. High speed craft are to be provided with arrangements for overriding automatic shutdown systems except in cases where there is a risk of complete breakdown or explosion.

2.4.10 The safety system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply.

2.4.11 Failure of any power supply to a safety system is to operate an audible and visual alarm.

2.4.12 When safety systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

2.5 Control systems

2.5.1 Where control systems are provided, the requirements of 2.5.2 to 2.5.11 are to be satisfied.

2.5.2 Control systems for machinery operations are to be stable throughout their operating range.

2.5.3 The control system is to be designed such that normal operation of the controls cannot induce detrimental mechanical or thermal overloads in the machinery.

2.5.4 When control systems are provided with means to adjust their sensitivity or set point, the arrangements are to be such that the final settings can be readily identified.

2.5.5 Control systems are to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the control system and its associated machinery, but also the complete installation.

2.5.6 Failure of any power supply to a control system is to operate an audible and visual alarm.

2.5.7 Where machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with the alarms and safety arrangements required by the appropriate Chapter(s). Alternative arrangements which provide equivalent safeguards will be considered.

2.5.8 Remote or automatic controls are to be provided with sufficient instrumentation at the relevant control stations to ensure effective control and indicate that the system is functioning correctly.

2.5.9 Where machinery is arranged to start automatically or from a remote control station, interlocks are to be provided to prevent start-up under conditions which could hazard the machinery.

2.5.10 Where machinery, controlled in accordance with 2.5.7, is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

2.5.11 Failure of a control system is not to result in the loss of ability to provide essential services by alternative means. This may be achieved by manual control or redundancy within the control system or redundancy in machinery and equipment, *see also* 2.12.2. Instrumentation is to be provided at local manual control stations to ensure effective operation of the machinery.

2.6 Bridge control for propulsion machinery

2.6.1 Where a bridge control system for propulsion machinery is to be fitted, the requirements of 2.6.2 to 2.6.8 are to be satisfied.

2.6.2 Means are to be provided to ensure satisfactory control of propulsion from the bridge in both the ahead and astern directions.

2.6.3 Two independent means are to be provided on the bridge to enable the watchkeeper to stop the propulsion machinery in an emergency.

2.6.4 Audible and visual alarms are to operate on the bridge and in the machinery alarm system if any power supply to the bridge control system fails. Where practicable the preset speed and direction of thrust are to be maintained until corrective action is taken.

2.6.5 Cargo (B) high speed craft are to be provided with a standby system for controlling propulsion machinery. A standby system controllable from an engine control space such as an engine control room outside the bridge is acceptable.

2.6.6 Passenger (B) high speed craft are to be provided with a standby system for controlling propulsion machinery from the bridge.

2.6.7 Passenger (B) high speed craft are to be provided with additional control of propulsion and manoeuvring at the same location as the emergency functions referred to in Pt 16, Ch 2,16.5.6. Such stations are to have direct communication with the bridge area.

2.6.8 For high speed craft, failure of the operating propulsion control system or of transfer of control is to bring the craft to low speed without hazarding passengers or craft.

2.7 Valve control systems

2.7.1 Where cargo, bilge, ballast, oil fuel transfer and sea valves for engine services are operated by remote or automatic control, the requirements of 2.7.2 to 2.7.5 are to be satisfied.

2.7.2 Failure of actuator power is not to permit a valve to move to an unsafe condition.

2.7.3 Positive indication is to be provided at the remote control station for the service to show the actual valve position or alternatively that the valve is fully open or closed.

2.7.4 Equipment located in places which may be flooded is to be capable of operating when submerged.

2.7.5 A secondary means of operating the valves, which may be by local manual control, is to be provided.

2.7.6 For requirements applicable to closing appliances on scuppers and sanitary discharges, *see* Pt 3, Ch 4,9.4. For power supplies on passenger craft, *see* Ch 2,3.2.

2.8 Fire detection alarm systems

2.8.1 Where an automatic fire detection system is to be fitted in a machinery space the requirements of 2.8.2 to 2.8.14 are to be satisfied.

2.8.2 A fire detection control unit is to be located in the navigating bridge area, the fire control station, or in some other position such that a fire in the machinery spaces will not render it inoperable.

2.8.3 Fire detection indicating panels are to denote the section in which a detector or manually operated call point has operated. At least one indicating panel is to be so located that it is easily accessible to responsible members of the crew at all times. An indicating panel is to be located on the navigating bridge, together with TV monitoring in the case of high speed craft.

2.8.4 An audible fire-alarm is to be provided having a characteristic which distinguishes it from the alarm system required by 2.3 or any other alarm system. The audible fire-alarm is to be immediately audible on all parts of the navigating bridge, at the fire control station and the machinery control stations, and throughout the crew accommodation areas and the machinery spaces.

2.8.5 Facilities are to be provided in the fire detection system to manually initiate the fire alarm from the following locations:

(a) Positions adjacent to all exits from machinery spaces.
(b) Navigating bridge.
(c) Control station in engine room.
(d) Fire control station.

2.8.6 The alarm system is to be designed with self-monitoring properties and system failures are to initiate an audible and visual alarm distinguishable from the fire alarm. This alarm may be incorporated in the machinery alarm system.

2.8.7 Power supplies for the alarm system are to be in accordance with 2.3.10 and 2.3.11.

2.8.8 Fire detection control units (including addressable systems), indicating panels, detector heads, manual call points and short circuit isolation units are to be Type Approved in accordance with the LR *Type Approval System*. For addressable systems, *see also* 2.10.

2.8.9 Detector heads are to be located in the machinery spaces so that all potential fire outbreak points are guarded. A combination of detectors is to be provided in order that the system will react to all possible fire characteristics.

2.8.10 When fire detectors are provided with means to adjust their sensitivity, the arrangements are to be such that the set point can be fixed and readily identified.

2.8.11 When it is intended that a particular loop is to be temporarily switched off, this state is to be clearly indicated at the fire detection indicating panels.

2.8.12 When it is intended that a particular detector(s) is (are) to be temporarily switched off locally, this state is to be clearly indicated at the local position. Reactivation of the detector(s) is to be performed automatically after a preset time.

2.8.13 The fire detector heads are to be of a type which can be tested and reset without the renewal of any component. Facilities are to be provided on the fire control panel for functional testing and reset of the system.

2.8.14 It is to be demonstrated to the Surveyor's satisfaction that detector heads are so located that air currents will not render the system ineffective at sea and in port.

2.9 Fixed water-based local application fire-fighting systems

2.9.1 Where fixed water-based local application fire-fighting systems are required to be installed by National Administration requirements, arrangements are to be in accordance with this sub-Section.

2.9.2 Systems are to be available for immediate use and arranged for manual activation from inside and outside the protected space. *See also* Ch 2,16.3.4.

2.9.3 Activation of a system is not to result in loss of electrical power or reduction of the manoeuvrability of the craft and is not to require confirmation of space evacuation or sealing.

2.9.4 A control panel is to be provided for managing actions such as opening of valves, starting of pumps and sounding of alarms and processing information from detectors.

2.9.5 Alarms are to be initiated upon activation of a system and are to indicate the specific zone released at the control panel. Alarms are to be provided in each protected space, at an attended machinery control station and in the wheelhouse. The audible alarm is to be distinguishable from other safety system alarms.

2.9.6 Where, additionally, the system is required to be capable of automatic release, the arrangements are to be in accordance with 2.9.7 to 2.9.9.

2.9.7 A minimum of two fire detectors is to be provided for each protected area. One is to be a flame detector and the other is to be a smoke or heat detector, as considered appropriate to the nature of the risk and ambient conditions. The system is to be activated upon detection by two of the detectors. A fault in one detector is to initiate an alarm and is not to inhibit activation of the system under the control of the other detector.

2.9.8 A fire detection alarm system panel in accordance with 2.8 may be used for receiving fire detection signals. Separate loops are not required provided that the address of the initiating device can be identified at the control panel. The received signals are then to be sent to the control panel required by 2.9.4 for processing and action.

2.9.9 The system's fire detection systems and control units are to meet the performance criteria stipulated by the National Administration and satisfy the requirements of LR's *Type Approval System Test Specification Number 1 (2002).*

2.10 Programmable electronic systems – General requirements

2.10.1 The requirements of this sub-Section are to be complied with where control, alarm or safety systems incorporate programmable electronic equipment. Systems for essential services and safety critical applications, systems incorporating shared data communication links and systems which are integrated are to comply with the additional requirements of 2.11, 2.12 and 2.13, as applicable. For systems complying with ISO 17894, *Ships and marine technology – Computer applications – General principles for the development and use of programmable electronic systems in marine applications, see* 2.1.2.

2.10.2 Where programmable electronic systems share resources, any components that can affect the ability to effectively provide required control, alarm or safety functions are to fulfil the requirements of 2.10 to 2.13 related to providing those required functions.

2.10.3 Programmable electronic equipment is to revert to a defined safe state on initial start up or re-start in the event of failure.

2.10.4 In the event of failure of any programmable electronic equipment, the system and any other system to which it is connected, is to fail to a defined safe state or maintain safe operation, as applicable.

2.10.5 Programmable electronic equipment is to be certified by a recognized authority as suitable for the environmental conditions in which it is intended to operate, *see also* 2.12.3.

2.10.6 Emergency stops are to be hard-wired and independent of any programmable electronic equipment. Alternatively, the system providing emergency stop functions is to comply with the requirements of 2.12.2 and/or 2.12.8.

2.10.7 Programmable electronic equipment is to be provided with self-monitoring capabilities such that hardware and functional failures will initiate an audible and visual alarm in accordance with the requirements of 2.3 and, where applicable, 3.2. Hardware failures indications are to enable faults to be identifiable at least down to the level of the lowest replaceable unit and the self-monitoring capabilities are to ensure that diagnostic information is readily available.

2.10.8 System configuration, programs and data are to be protected against loss or corruption in the event of failure of any power supply.

2.10.9 Access to system configuration, programs and data is to be restricted by physical and/or logical means providing effective security against unauthorized alteration.

2.10.10 Where date and time information is required by the equipment, this is to be provided by means of a battery backed clock with restricted access for alteration. Date and time information is to be fully represented and utilized.

2.10.11 Displays and controls are to be protected against liquid ingress due to spillage.

2.10.12 User interfaces are to be designed in accordance with appropriate ergonomic principles to meet user needs and enable timely access to desired information or control of functions. A system overview is to be readily available.

2.10.13 The keyboard is to be divided logically into functional areas. Alphanumeric, paging and specific system keys are to be grouped separately.

2.10.14 Where a function may be accessed from more than one interface, the arrangement of displays and controls is to be consistent.

2.10.15 The size, colour and density of information displayed to the operator are to be such that information may be easily read from the normal operator position under all operational lighting conditions.

2.10.16 Display units are to comply with the requirements of International Electrotechnical Commission Standard IEC 60950:1991, *Safety of information technology equipment, including electrical business equipment*, in respect of emission of ionising radiation.

2.10.17 Symbols used in mimic diagrams are to be visually representative and are to be consistent throughout the systems' displays.

2.10.18 Where systems detect fault conditions, any affected mimic diagrams are to ensure that the status of unreliable and incorrect data is clearly identified.

2.10.19 Multi-function displays and controls are to be duplicated and interchangeable where used for the control or monitoring of more than one system, machinery item or item of equipment. At least one unit at the main control station is to be supplied from an independent uninterruptible power system (UPS).

2.10.20 The number of multi-function display and control units provided at the main control station and their power supply arrangements are to be sufficient to ensure continuing safe operation in the event of failure of any unit or any power supply.

2.10.21 Software lifecycle activities, e.g. design, development, supply and maintenance, are to be carried out in accordance with an acceptable quality management system. Software quality plans are to be submitted. These are to demonstrate that the provisions of ISO/IEC 90003:2004, *Software engineering – Guidelines for the application of ISO 9001:2000 to computer software*, or equivalent, are incorporated. The plans are to define responsibilities for the lifecycle activities, including verification, validation, module testing and integration with other components or systems.

2.11 Data communication links

2.11.1 Where control, alarm or safety systems use shared data communication links to transfer data, the requirements of 2.11.2 to 2.11.10 are to be complied with. The requirements apply to local area networks, fieldbuses and other types of data communication link which make use of a shared medium to transfer control, alarm or safety related data between distributed programmable electronic equipment or systems.

2.11.2 Data communication is to be automatically restored within 45 seconds in the event of a single component failure. Upon restoration, priority is to be given to updating safety critical data and control, alarm and safety related data for essential services. Components comprise all items required to facilitate data communication, including cables, switches, repeaters, software components and power supplies.

2.11.3 Loss of a data communication link is not to result in the loss of ability to operate any essential service by alternative means, *see also* 2.12.2.

2.11.4 The properties of the data communication link, (e.g. bandwidth, access control method, etc.), are to ensure that all connected systems will operate in a safe, stable and repeatable manner under all operating conditions. The latency of control, alarm and safety related data is not to exceed two seconds.

2.11.5 Protocols are to ensure the integrity of control, alarm and safety related data, and provide timely recovery of corrupted or invalid data.

2.11.6 Means are to be provided to monitor performance and identify hardware and functional failures. An audible and visual alarm is to operate in accordance with the requirements of 2.3 and, where applicable, 3.2 in the event of a failure of an active or standby component.

2.11.7 Means are to be provided to prevent unintended connection or disconnection of any equipment where this may affect the performance of any other systems in operation.

2.11.8 Data cables are to comply with the applicable requirements of Pt 16, Ch 2,10. Other media will be subject to special consideration.

2.11.9 The installation is to provide adequate protection against mechanical damage and electromagnetic interference.

2.11.10 Components are to be located with appropriate segregation such that the risk of mechanical damage or electromagnetic interference resulting in the loss of both active and standby components is minimized. Duplicated data communication links are to be routed to give as much physical separation as is practical.

2.12 Programmable electronic systems – Additional requirements for essential services and safety critical systems

2.12.1 The requirements of 2.12.2 to 2.12.9 are to be complied with where control, alarm or safety systems for essential services, as defined by Pt 16, Ch 2,1.5, or safety critical systems, incorporate programmable electronic equipment:

(a) Safety critical systems are those which provide functions intended to protect persons from physical hazards (e.g. fire, explosion, etc.), or to prevent mechanical damage which may result in the loss of an essential service (e.g. main engine low lubricating oil pressure shutdown).

(b) Applications that are not essential services may also be considered to be safety critical (e.g. domestic boiler low water level shutdown).

2.12.2 Alternative means of safe and effective operation are to be provided for essential services and, wherever practicable, these are to be by provision of a fully independent hard wired back-up system. Where these alternative means are not independent of any programmable electronic equipment, the software is to satisfy the requirements of LR's *Software Conformity Assessment System - Assessment Module GEN1 (1994)*.

2.12.3 Items of programmable electronic equipment used to implement control, alarm and safety functions are to satisfy the requirements of LR's *Type Approval System Test Specification Number 1* (2002).

2.12.4 The system is to be configured such that control, alarm and safety function groups are independent. A failure of the system is not to result in the loss of more than one of these function groups. Proposals for alternative arrangements providing an equivalent level of safety will be subject to special consideration.

2.12.5 For essential services, the system is to be arranged to operate automatically from an alternative power supply in the event of a failure of the normal supply.

2.12.6 Failure of any power supply is to initiate an audible and visual alarm in accordance with the requirements of 2.3 and, where applicable, 3.2.

2.12.7 Where it is intended that the programmable electronic system implements emergency stop or safety critical functions, the software is to satisfy the requirements of LR's *Software Conformity Assessment System - Assessment Module GEN1 (1994)*. Alternative proposals providing an equivalent level of system integrity will be subject to special consideration, e.g. fully independent hard wired back-up system, redundancy with design diversity, etc.

2.12.8 Control, alarm and safety related information is to be displayed in a clear, unambiguous and timely manner, and, where applicable, is to be given visual prominence over other information on the display.

2.12.9 Means of access to safety critical functions are to be dedicated to the intended function and readily distinguishable.

2.13 Programmable electronic systems - Additional requirements for integrated systems

2.13.1 The requirements of 2.13.2 to 2.13.7 apply to integrated systems providing control, alarm or safety functions in accordance with the Rules, including systems capable of independent operation interconnected to provide co-ordinated functions or common user interfaces. Examples include integrated machinery control, alarm and monitoring systems, power management systems and safety management systems providing a grouping of fire, passenger, crew or craft safety functions, *see* Ch 2,16 to 18.

2.13.2 System integration is to be managed by a single designated party, and is to be carried out in accordance with a defined procedure identifying the roles, responsibilities and requirements of all parties involved. This procedure is to be submitted for consideration where the integration involves control functions for essential services or safety functions including fire, passenger, crew, and craft safety.

2.13.3 The system requirements specification, *see* 1.2.5, is to identify the allocation of functions between modules of the integrated system, and any common data communication protocols or interface standards required to support these functions.

2.13.4 Reversionary modes of operation are to be provided to ensure safe and graceful degradation in the event of one or more failures. In general, the integrated system is to be arranged such that the failure of one part will not affect the functionality of other parts, except those that require data from the failed part

2.13.5 Where the integration involves control functions for essential services or safety functions, including fire, passenger, crew and craft safety, a Failure Mode and Effects Analysis (FMEA) is to be carried out in accordance with IEC 60812, or an equivalent and acceptable National or International Standard and the report and worksheets submitted for consideration. The FMEA is to demonstrate that the integrated system will 'fail-safe', *see* 2.4.6 and 2.5.5, and that essential services in operation will not be lost or degraded beyond acceptable performance criteria where specified by these Rules.

2.13.6 The quantity and quality of information presented to the operator are to be managed to assist situational awareness in all operating conditions. Excessive or ambiguous information that may adversely affect the operator's ability to reason or act correctly is to be avoided, but information needed for corrective or emergency actions is not to be suppressed or obscured in satisfying this requirement.

2.13.7 Where information is required by the Rules or by National Administration requirements to be continuously displayed, the system configuration is to be such that the information may be viewed without manual intervention, e.g. the selection of a particular screen page or mode of operation. *See also* 2.10.19 and 2.10.20.

■ *Section 3* Unattended machinery space(s) – UMS notation

3.1 General

3.1.1 Where it is proposed to operate the following machinery in an unattended space, no matter what period is envisaged, the controls, alarms and safeguards required by the appropriate Chapters together with those given in 3.2 to 3.7 are to be provided:

- Air compressors.
- Controllable pitch propellers.
- Electric generating plant.
- Oil fuel transfer and storage systems.
- Propulsion machinery including essential auxiliaries.
- Steam raising plant (boilers and their ancillary equipment).
- Thermal fluid heaters.

3.2 Alarm system for machinery

3.2.1 An alarm system which will provide warning of faults in the machinery is to be installed. The system is to satisfy the requirements of 2.3.

3.2.2 Audible and visual indication of machinery alarms is to be relayed to the engineers' accommodation so that engineering personnel are made aware that a fault has occurred.

3.2.3 The engineers' alarm required by 2.2.3 is to be activated automatically in the event that a machinery alarm has not been acknowledged in the space within a predetermined time.

3.2.4 Audible and visual indication of machinery alarms is to be relayed to the navigating bridge control station in such a way that the navigating officer of the watch is made aware when:

(a) a machinery fault has occurred,
(b) the machinery fault is being attended to, and
(c) the machinery fault has been rectified.

3.2.5 Group alarms may be arranged on the bridge to indicate machinery faults, but alarms associated with faults requiring speed or power reduction or the automatic shutdown of propulsion machinery are to be identified by separate group alarms or by individual alarm parameters.

3.3 Bridge control for propulsion machinery

3.3.1 A bridge control system for the propulsion machinery is to be fitted. The system is to satisfy the requirements of 2.6.

3.4 Control stations for machinery

3.4.1 A control station(s) is to be provided in the space and on the bridge which satisfies the requirements of 2.2.

3.5 Fire detection alarm system

3.5.1 An automatic fire detection system is to be fitted in the space together with an audible and visual alarm system. The system is to satisfy the requirements of 2.8.

3.6 Bilge level detection

3.6.1 An alarm system is to be provided to warn when liquid in machinery space bilges has reached a predetermined level, and is to comply with 2.3. This level is to be sufficiently low to prevent liquid from overflowing from the bilges onto the tank top. The number and location of detectors are to be such that accumulation of liquids will be detected at all angles of heel and trim.

3.6.2 Local or remote controls of any valve within the space serving a sea inlet, a discharge below the waterline, a bilge injection or a direct bilge system, should be so sited as to be readily accessible and to allow adequate time for operation in case of influx of water to the space, having regard to the time which could be taken to reach and operate such controls.

3.6.3 Where the bilge pumps are arranged to start automatically, means are to be provided to indicate if the influx of liquids is greater than the pump capacity or, if the pump is operating more frequently than would be expected. Special attention should be given to oil pollution prevention requirements.

3.7 Supply of electric power, general

3.7.1 For craft operating with one generator set in service, arrangements are to be such that a standby generator will automatically start and connect to the switchboard in as short a time as practicable, but in any case within 45 seconds, on loss of the service generator. For craft operating with two or more generator sets in service, arrangements are to be such that on loss of one generator the remaining one(s) are to be adequate for continuity of essential services. For the detailed requirements of these arrangements, *see* Ch 2,2.2.

■ *Section 4*
Machinery operated from a centralized control station – CCS notation

4.1 General requirements

4.1.1 Where it is proposed to operate the machinery as listed in 3.1.1 with continuous supervision from a centralized control station, the control station is to be such that the machinery operation will be as effective as it would be under direct supervision.

4.1.2 The arrangements are to be such that corrective actions can be taken at the control station in the event of machinery faults, e.g. stopping of machinery, starting of standby machinery, adjustment of operating parameters, etc. These actions may be effected by either remote manual or automatic control.

4.1.3 The controls, alarms and safeguards required by the appropriate Chapters and by 3.6 together with a fire detection system satisfying the requirements of 2.8 are to be provided.

4.1.4 Additional requirements for controls, alarms and safeguards are given in 4.2.

4.2 Centralized control station for machinery

4.2.1 A centralized control station is to be provided at some suitable location, which satisfies the requirements of 4.2.2 to 4.2.7.

4.2.2 A system of alarm displays and controls is to be provided which readily ensures identification of faults in the machinery and satisfactory supervision of related equipment. The alarm and control systems are to satisfy the requirements of 2.3 and 2.5, as applicable.

4.2.3 Indication of all essential parameters necessary for the safe and effective operation of the machinery is to be provided, e.g. temperatures, pressures, tank levels, speeds, powers, etc.

4.2.4 Indication of the operational status of running and standby machinery is to be provided.

4.2.5 At the centralized control station, means of communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery space are to be provided.

4.2.6 In addition to the communication required by 4.2.5, a second means of communication is to be provided between the bridge and the centralized control station. One of these means is to be independent of the main electrical power supply.

4.2.7 Arrangements are to be provided in the centralized control station so that the normal supply of electrical power may be restored in the event of failure.

Section 5
Requirements for craft which are not required to comply with the HSC Code

5.1 General

5.1.1 The relevant requirements of Sections 1 and 2 are to be complied with.

5.1.2 For vessels which are to be assigned or to be eligible for the **UMS** or **CCS** notations the requirements of Sections 3 and 4 are to be complied with.

5.1.3 For yachts less than 500 gt and small craft not requiring the **UMS** and **CCS** notation, the requirements of 5.2 and 5.3 apply.

5.1.4 Yachts that are 500 gt or more are to comply with the requirements of Sections 1 and 2.

5.2 Plans and information

5.2.1 Plans are required to be submitted in accordance with 1.2 only for the machinery items applicable to these craft.

5.3 Control and supervision of unattended machinery

5.3.1 Where machinery items applicable to these craft are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators they are to be provided with the alarms and safety arrangements specified in the appropriate Chapters of the Rules.

Section 6
Trials

6.1 General

6.1.1 Before a new installation (or any alteration or addition to an existing installation) is put into service, trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works and are to be based on the approved test schedules list as required by 1.2.3. In the case of new construction it will be expected that most of these trials will be carried out before the official sea trials of the craft. During sea trials, system dynamic tests are to be carried out to demonstrate overall satisfactory performance of the control engineering installation.

6.1.2 Means are to be provided to facilitate testing during normal machinery operation, e.g. by the provision of three-way test valves or equivalent.

6.1.3 Acceptance tests and trials for Programmable Electronic Systems are to include verification of software lifecycle activities appropriate to the stage in the system's lifecycle at the time of system examination.

6.2 Unattended machinery space operation – UMS notation

6.2.1 In addition to the tests required by 6.1, the suitability of the installation for operation in the unattended mode is to be demonstrated during sea trials observing the following:

(a) Occurring alarms and the frequency of operation both during steady steaming and under manoeuvring conditions using bridge control.
(b) Any intervention by personnel in the operation of the machinery.

6.3 Operation from a centralized control station – CCS notation

6.3.1 In addition to the tests required by 6.1, the suitability of the installation for operation from the centralized control station is to be demonstrated during sea trials.

6.4 Record of trials

6.4.1 Two copies of the alarm and control equipment test schedules, as required by 1.2.3, signed by the Surveyor and Builder are to be provided on completion of the survey. One copy is to be placed on board the vessel and the other submitted to LR.

Section

■ *Section 1* General requirements

1.1 General

1.1.1 The requirements of Sections 1 to 18 and 20 are, in general, applicable to all the craft types indicated in Pt 1, Ch 2,2.1, with the exception of cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and for yachts less than 500 gt, which are covered in Section 19.

1.1.2 Whilst this Chapter applies to the electrical engineering equipment and systems on special service craft intended to be classed, attention should also be given to any relevant Statutory Regulations of the National Authority of the country in which the craft is to be registered and the Code of Safety for High Speed Craft.

1.1.3 Electrical services required to maintain the craft in a normal seagoing, operational and habitable condition are to be capable of being maintained without recourse to the emergency source of electrical power.

1.1.4 Electrical services essential for safety are to be maintained under various emergency conditions.

1.1.5 The safety of passengers, crew and craft from electrical hazards is to be ensured.

1.1.6 Consideration will be given to special cases or to arrangements which are equivalent to the Rules.

1.2 Plans

1.2.1 At least three copies of the plans and particulars in 1.2.2 to 1.2.8 are to be submitted for consideration. Single copies only are required of plans in 1.2.9 to 1.2.12. Additional copies are to be submitted when requested.

1.2.2 Single line diagram of main and emergency power and lighting systems which is to include:
(a) ratings of machines, transformers, batteries and semi-conductor converters;
(b) all feeders connected to the main and emergency switchboards;
(c) section boards and distribution boards;
(d) insulation type, size and current loadings of cables;
(e) make, type and rating of circuit breakers and fuses;
(f) details of harmonic filters (where fitted).

1.2.3 Simplified diagrams of generator circuits, inter-connector circuits and feeder circuits showing:
(a) protective devices, e.g. short circuit, overload, reverse power protection;
(b) instrumentation and synchronizing devices;
(c) preference tripping;
(d) remote stops;
(e) earth fault indication/protection.

1.2.4 Calculations of short circuit currents at main and emergency switchboards and section boards including those fed from transformers, with details of circuit breaker and fuse operating times and discrimination curves showing compliance with 6.1 and 10.6.2.

1.2.5 A test schedule which is to include the method of testing and the test facilities which are provided for the general emergency alarm system and the public address system.

1.2.6 For battery installations, arrangement plans and calculations to show compliance with Section 11.

1.2.7 A schedule of batteries fitted for use for emergency and essential services, giving details of:
- type and manufacturer's type designation;
- voltage and ampere-hour rating;
- location;
- equipment and/or system(s) served;
- maintenance/replacement cycle dates;
- date(s) of maintenance and/or replacement; and
- for replacement batteries in storage, the date of manufacture and shelf life, with accompanying battery replacement procedure documentation to show compliance with 11.8.

1.2.8 Details of electrically-operated fire, craft, crew and passenger emergency safety systems which are to include typical single line diagrams and arrangements, showing main vertical and, where applicable, horizontal fire zones and the location of equipment and cable routes to be employed for:
(a) emergency lighting;
(b) accommodation fire detection, alarm and extinction systems;
(c) fixed water-based local application fire-fighting systems;
(d) public address system;
(e) general alarm;
(f) watertight doors, shell doors and other electrically operated closing appliances;
(g) low location lighting.

NOTE
A general arrangement plan of the complete craft showing the main vertical fire zones and the location of equipment and cable routes, for the above systems, is to be made available for the use of the Surveyor on board.

1.2.9 In order to establish compliance with 1.10.2 and 5.1.3 to 5.1.5, a general arrangement plan of the craft showing the location of major items of electrical equipment, for example:
- main and emergency generators;
- switchboards;
- section boards and distribution boards supplying essential and emergency services;
- emergency batteries;
- motors for emergency services; and
- cable routes between these items of equipment.

1.2.10 Arrangement plans of main and emergency switchboards, and section boards.

1.2.11 Schedule of normal and emergency operating loads on the system estimated for the different operating conditions expected.

1.2.12 In order to establish compliance with the requirements of 1.6.3, evidence is to be submitted to demonstrate the suitability of electrical equipment for its intended purpose in the conditions in which it is expected to operate.

1.3 Surveys

1.3.1 Electrical machinery and auxiliary services essential for the safety of the craft are to be installed in accordance with the relevant requirements of this Chapter, surveyed and have tests witnessed by the Surveyors.

1.3.2 The following equipment, where intended for use for essential and emergency services, is to be surveyed by the Surveyors during manufacture and testing:
- Converting equipment of 100 kW and over;
- Rotating machines of 100 kW and over;
- Switchboards and section boards; and
- UPS units of 50 kVA and over.

1.3.3 All other electrical equipment, not specifically referenced in 1.3.2, intended for use for essential or emergency services is to be supplied with a manufacturer's works test certificate showing compliance with the constructional standard(s) as referenced by the relevant requirements of this Chapter.

1.4 Additions or alterations

1.4.1 No addition, temporary or permanent, is to be made to the approved load of an existing installation until it has been ascertained that the current carrying capacity and the condition of the existing equipment including cables and switchgear are adequate for the increased load.

1.4.2 Plans are to be submitted for consideration, and the alterations or additions are to be carried out under the survey, and to the satisfaction of the Surveyors.

1.4.3 When it is proposed to replace permanently installed secondary valve-regulated sealed batteries with vented batteries, details are to be submitted for consideration to ensure continued safety in the presence of the products of electrolysis and evaporation being allowed to escape freely from the cells to the atmosphere. These details are to demonstrate that there will be adequate ventilation in accordance with 11.5.9 and that the location and installation requirements of 11.3 and 11.4 are complied with.

1.5 Definitions

1.5.1 Essential services are those necessary for the propulsion and safety of the craft, such as the following:
- air compressors for starting and manoeuvring essential mains and auxiliary machinery;
- air pumps:
- automatic sprinkler systems;
- ballast pumps;
- bilge pumps;
- circulating and cooling water pumps;
- communication systems;
- electric starting systems for starting and manoeuvring essential main and auxiliary machinery;
- fire detection and alarm systems;
- fire pumps;
- fuel valve cooling pumps;
- hydraulic pumps for controllable pitch propellers and those serving essential services here listed that would otherwise be directly electrically-driven;
- hydraulic pumps serving essential services here listed which would otherwise be directly electrically driven;
- lubricating oil pumps;
- lighting systems for those parts of the craft normally accessible to and used by personnel and passengers;

- navigational aids where required by Statutory Regulations;
- navigation lights and special purpose lights where required by Statutory regulations;
- oil fuel pumps and oil fuel burning units;
- pumps for fire-extinguishing systems;
- scavenge blowers;
- steering gear;
- valves which are required to be remotely operated;
- ventilating fans for engine rooms;
- watertight doors, shell doors and other electrical operated closing appliances;
- windlasses;
- power sources and supply systems for supplying the above services.

1.5.2 Services such as the following are considered necessary for minimum comfortable conditions of habitability:

- cooking;
- heating;
- domestic refrigeration;
- mechanical ventilation;
- sanitary and fresh water.

1.5.3 Services such as the following, which are additional to those in 1.5.1 and 1.5.2, are considered necessary to maintain the craft in a normal seagoing operational and habitable condition:

- cargo handling and cargo care equipment;
- hotel services, other than those required for habitable conditions;
- thruster systems for manoeuvring.

1.5.4 A ‘high voltage’ is a voltage exceeding 1000 V a.c. or 1500 V d.c. between conductors (*see also* 5.1.2).

1.5.5 A ‘switchboard’ is a switchgear and control gear assembly for the control of power generated by a source of electrical power and its distribution to electrical consumers.

1.5.6 A ‘section board’ is a switchgear and control gear assembly for controlling the supply of electrical power from a switchboard and distributing it to other section boards, distribution boards or final sub-circuits.

1.5.7 A ‘distribution board’ is an assembly of one or more protective devices arranged for the distribution of electrical power to final sub-circuits.

1.5.8 A ‘final sub-circuit’ is that portion of a wiring system extending beyond the final overcurrent device of a board.

1.5.9 ’Special Category spaces’ are those enclosed spaces above or below the bulkhead deck intended for the carriage of motor vehicles with fuel, for their own propulsion, in their tanks, into and from which such vehicles can be driven, and to which passengers have access.

1.5.10 'Machinery spaces of Category A' are those spaces and trunks to such spaces which contain:

(a) internal combustion machinery used for main propulsion; or

(b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or

(c) any oil-fired boiler or oil fuel unit.

1.5.11 ‘Dead craft condition’ means that the entire machinery installation, including the power supply, is out of operation and that the auxiliary services for bringing the main propulsion systems into operation (e.g. compressed air, starting current from batteries, etc.) and for the restoration of the main power supply are not available. Means are to be available at all times to start the emergency generator, *see* Pt 10, Ch 1,7.6.

1.5.12 Protected space is a machinery space where a fixed water-based local application fire-fighting system is installed.

1.5.13 Protected areas are areas within a protected space which is required to be protected by a fixed water-based local application fire-fighting system.

1.5.14 Adjacent areas are areas, other than protected areas, exposed to direct spray or other areas where water may extend when a fixed water-based local application fire-fighting system is activated.

1.6 Design and construction

1.6.1 Equipment for services essential for the safety of the craft are to be constructed in accordance with the relevant requirements of this Chapter.

1.6.2 The design and installation of other equipment is to be such that risk of fire due to its failure is minimised. It is to, as a minimum, comply with a National or International Standard revised where necessary for ambient conditions.

1.6.3 Electrical equipment is to be suitable for its intended purpose and accordingly, whenever practicable to be selected from the *List of Type Approved Products* published by Lloyd’s Register’s (hereinafter referred to as ‘LR’). A copy of the Procedure for LR Type Approval System will be supplied on application.

1.7 Quality of power supplies

1.7.1 All electrical equipment supplied from the main and emergency sources of electrical power and electrical equipment for essential and emergency services supplied from d.c. sources of electrical power is to be so designed and manufactured that it is capable of operating satisfactorily under normally occurring variations of voltage and frequency.

1.7.2 Unless specified otherwise, a.c. electrical equipment is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals. Alarms are to be provided for High and Low Voltage and Low Frequency.

(a) Voltage:
- permanent variations +6%, –10%
- transient variations due to step changes in load ±20%
- recovery time 1,5 seconds.

(b) Frequency:
- permanent variations ±5%
- transient variations due to step changes in load ±10%
- recovery time 5 seconds.

A maximum rate of change of frequency not exceeding ±1,5 Hz per second during cyclic frequency fluctuations.

1.7.3 Harmonics. Unless specified otherwise, the total harmonic distortion (THD) of the voltage waveform at any a.c. switchboard or section-board is not to exceed 8 per cent of the fundamental for all frequencies up to 50 times the supply frequency and no voltage at a frequency above 25 times supply frequency is to exceed 1,5 per cent of the fundamental of the supply voltage. THD is the ratio of the rms value of the harmonic content to the rms value of the fundamental, expressed in per cent and may be calculated using the expression:

$$THD = \frac{\sqrt{\sum_{h=2}^{\infty} V_h^2}}{V_1} 100$$

where
V_h = rms amplitude of a harmonic voltage of order *h*
V_1 = rms amplitude of the fundamental voltage.

1.7.4 Unless specified otherwise, d.c. electrical equipment is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals:

(a) When supplied by d.c. generator(s) or a rectified a.c. supply:
Voltage tolerance (continuous) ±10%
Voltage cyclic variation deviation 5%
Voltage ripple 10%
(a.c. rms over steady state d.c. voltage);

(b) When supplied by batteries:
(i) Equipment connected to the batteries during charging:
Voltage tolerance +30%, -25%;
(ii) Equipment not connected to batteries during charging:
Voltage tolerance +20%, -25%

Different voltage variations as determined by the charging/discharging characteristics, including ripple voltage from the charging device, may be considered. When battery chargers/battery combinations are used as d.c. power supply systems adequate measures are to be taken to keep the voltage within the specified limits during charging, boost charging and discharging of the battery.

1.8 Ambient reference and operating conditions

1.8.1 The rating for classification purposes of essential electrical equipment intended for installation in craft to be classed for unrestricted (geographical) service is to be based on an engine room ambient temperature of 45°C, and a seawater temperature at the inlet of 32°C. The equipment manufacturer is not expected to provide simulated ambient reference conditions at a test bed.

1.8.2 In the case of craft to be classed for restricted service, the rating is to be suitable for the ambient conditions associated with the geographical limits of the restricted service which are part of the class notation.

1.8.3 Main and essential auxiliary machinery and equipment is to operate satisfactorily under the conditions shown in Pt 9, Ch 1,4.4. Electrical equipment satisfying alternative ambient operating condition requirements for installation on ships contained in an acceptable and relevant national or international standard may be considered to satisfy this requirement.

NOTE
Details of local environmental conditions are stated in Annex B of IEC 60092: *Electrical installations in ships – Part 101: Definitions and general requirements.*

1.8.4 Where electrical equipment is installed within environmentally controlled spaces, the ambient temperature for which the equipment is suitable for operation at its rated capacity may be reduced to a value not less than 35°C provided:
- the equipment is not for use for emergency services and is located outside of machinery space(s);
- temperature control is achieved by at least two cooling units so arranged that, in the event of loss of one cooling unit, for any reason, the remaining unit(s) will be capable of satisfactorily maintaining the design temperature;
- the equipment is able to be initially set to work safely within a 45°C ambient temperature until such a time that the lesser ambient temperature may be achieved; the cooling equipment is to be rated for an ambient temperature of not less than 45°C; and
- alarms are provided, at a continually attended control station, to indicate any malfunction of the cooling units.

See also Pt 16, Ch 1,1.3.3.

1.8.5 Where equipment is to comply with 1.8.4, it is to be ensured that electrical cables for their entire length are adequately rated for the maximum ambient temperature to which they are exposed along their length.

1.8.6 Equipment used for cooling and maintaining the lesser ambient temperature in accordance with 1.8.4 are considered essential services and are to satisfy the requirements of 5.2.

1.9 Inclination of craft

1.9.1 Emergency and essential electrical equipment is to operate satisfactorily under the conditions as shown in Table 1.4.1 in Pt 9, Ch 1.

1.10 Location and construction

1.10.1 All electrical equipment is to be constructed or selected, and installed such that:

(a) live parts cannot be inadvertently touched, unless they are supplied at the safety voltage specified in 1.11.2(h);
(b) it does not cause injury when handled or touched in the normal manner; and
(c) it is unaffected by any water, steam or oil and oil vapour to which it is likely to be exposed.

Electrical equipment having, as a minimum, the degrees of protection as specified in IEC 60092-201 for the relevant location will satisfy these requirements.

1.10.2 Switchboards, section boards and distribution boards supplying essential and emergency services, as well as cables from the respective generators to and between these boards, are to be arranged to avoid areas of high fire risk and elevated temperatures, for example, in close proximity to incinerators and boilers.

1.10.3 Electrical equipment, as far as is practicable, is to be located:

(a) such that it is accessible for the purpose of maintenance and survey;
(b) clear of flammable material;
(c) in spaces adequately ventilated to remove the waste heat liberated by the equipment under full load conditions, at the ambient conditions specified in 1.8;
(d) where flammable gases cannot accumulate. If this is not practicable, electrical equipment is to be of the appropriate 'safe-type', *see* Section 13;
(e) where it is not exposed to the risk of mechanical injury or damage from water, steam or oil.

1.10.4 Equipment design and the choice of materials are to reduce the likelihood of fire, ensuring that:

(a) where the electrical energized part can cause ignition and fire, it is contained within the bounds of the enclosure of the electrotechnical product;
(b) the design, material(s) and construction of the enclosure minimises, as far as is practicable, any internal ignition causing ignition of adjacent materials; and
(c) where surfaces of the electrotechnical products can be exposed to external fire, they do not, as far as practicable, contribute to the fire growth.

NOTE
Compliance with IEC 60695: *Fire hazard testing*, or an alternative and acceptable Standard, will satisfy this requirement, *see also* 1.14.4.

1.10.5 Insulating materials and insulated windings are to be resistant to tracking, moisture, sea air, oil and oil vapour unless special precautions are taken to protect them.

1.10.6 Studs, screw-type or spring-type clamp terminations, satisfactory for the normal operating currents and voltages, are to be provided in electrical equipment for the connection of external cable, or bus-bar conductors, as appropriate, *see also* 10.14. There is to be adequate space and access for the terminations.

1.10.7 Equipment is not to remain alive through the control circuits and/or pilot lamps when switched off by the control switch. This does not apply to synchronizing switches and/or plugs.

1.10.8 The operation of all electrical equipment and the lubrication arrangements are to be efficient under such conditions of vibration and shock as arise in normal practice.

1.10.9 All nuts, screws and clamping devices used in connection with current-carrying, supporting and working parts are to be provided with means to ensure that they cannot work loose by vibration and shock as arise in normal practice.

1.10.10 Conductors and equipment are to be placed at such a distance from the magnetic compasses, or are to be so disposed, that the interfering magnetic field is negligible when circuits are switched on and off.

1.10.11 Where electrical power is used for propulsion, the equipment is to be so arranged that it will operate satisfactorily in the event of partial flooding by bilge water above the tank top up to the bottom floor plate level, under the normal angles of inclination given in 1.9 for essential electrical equipment, *see* Pt 15, Ch 2.

1.11 Earthing of non-current carrying parts

1.11.1 Except where exempted by 1.11.2, all non-current carrying exposed metal parts of electrical equipment and cables are to be earthed.

1.11.2 The following parts may be exempted from the requirements of 1.11.1:

(a) lamp-caps, where suitably shrouded;
(b) shades, reflectors and guards supported on lampholders or light fittings constructed of, or shrouded in, non-conducting material;
(c) metal parts on, or screws in or through, non-conducting materials, which are separated by such material from current-carrying parts and from earthed non-current carrying parts in such a way that in normal use they cannot become live or come into contact with earthed parts;
(d) apparatus which is constructed in accordance with the principle of double insulation;
(e) bearing housings which are insulated in order to prevent circulation of current in the bearings;
(f) clips for fluorescent lamps;
(g) cable clips and short lengths of pipes for cable protection;
(h) apparatus supplied at a safety voltage not exceeding 50 V d.c. or 50 V a.c., between conductors, or between any conductor and earth in a circuit isolated from the supply. Autotransformers are not to be used for the purpose of achieving the alternating current voltage;
(j) apparatus or parts of apparatus which although not shrouded in insulating material is nevertheless otherwise so guarded that it cannot be touched and cannot come in contact with exposed metal.

1.11.3 Armouring, braiding and other metal coverings of cables are to be effectively earthed. Where the armouring, braiding and other metal coverings are earthed at one end only, they are to be adequately protected and insulated at the unearthed end with the insulation being suitable for the maximum voltage that may be induced. *See* 13.1 for earthing of cables in dangerous zones or spaces.

1.11.4 The electrical continuity of all metal coverings of cables throughout the length of the cable, particularly at joints and tappings, is to be ensured.

1.11.5 Metal parts of portable appliances, other than current-carrying parts and parts exempted by 1.11.2 are to be earthed by means of an earth-continuity conductor in the flexible cable or cord through the associated plug and socket-outlet.

1.11.6 Earthing conductors are to be of copper or other corrosion-resistant material and be securely installed and protected where necessary against damage and also, where necessary, against electrolytic corrosion. Connections are to be so secured that they cannot work loose under vibration.

1.11.7 The nominal cross-section areas of copper earthing conductors are, in general to be equal to the cross-section of the current-carrying conductor up to 16 mm^2. Above this figure they are to be equal to at least half the cross-section of the current-carrying conductor with a minimum of 16 mm^2. Every other earthing conductor is to have a conductance not less than that specified for an equivalent copper earthing conductor.

1.11.8 The connection of the earthing conductor to the hull of the craft is to be made in an accessible position, and is to be secured by a screw or stud of diameter not less than 6 mm which is to be used for this purpose only. Bright metallic surfaces at the contact areas are to be ensured immediately before the nut or screw is tightened and, where necessary, the joint is to be protected against electrolytic corrosion. The connection is to remain unpainted.

1.12 Electrical bonding for the control of static electricity

1.12.1 In non-metallic craft, all metallic parts of the craft are to be electrically bonded together, as far as possible, in consideration of galvanic corrosion between dissimilar metals, to ensure an earth return path and to connect the craft to the water when water-borne. This does not apply to isolated components which cannot become live, nor require control of static electricity.

1.12.2 Bonding straps for the control of static electricity are required for piping systems, including pressure refuelling points, which are not electrically continuous throughout their length and for flammable products, which are not permanently connected to the hull of the craft either directly or via their bolted or welded supports and where the resistance between them and the hull exceeds 1MΩ.

1.12.3 Where bonding straps are required for the control of static electricity, they are to be robust, that is, having a cross-sectional area of about 10 mm^2, and are to comply with 1.11.6 and 1.11.8.

1.13 Alarms

1.13.1 Where alarms are required by this Chapter they are to be arranged in accordance with Ch 1,2.3. Sound signal equipment, fire and general alarm bells are not required to be supplemented by visual alarms, except in areas having high levels of background noise, such as machinery spaces.

1.13.2 The alarms in this Chapter are additional to those required by Chapter 1. They may however form part of the alarm system that is required by Chapter 1.

1.13.3 Cables for emergency alarms and their power sources are to be in accordance with 1.14.

1.13.4 Electrical equipment and cables for emergency alarms are to be so arranged that the loss of alarms in any one area due to localised fire, collision, flooding or similar damage is minimised, *see* 1.14.

1.14 Operation under fire conditions

1.14.1 As a minimum, the following emergency services and their emergency power supplies, are required to be capable of being operated under fire conditions:

- Emergency fire pump.
- Fire safety stops, see also 16.6.
- Control and power systems to power-operated fire doors and their status indication.
- Control and power systems to power-operated water-tight doors and their status indication.
- Emergency lighting.
- Fire and general alarms.
- Fire detection systems.
- Fire-extinguishing systems and fire-extinguishing media release alarms.
- Low location lighting, *see also* 17.4.3.
- Public address systems.

1.14.2 Where cables for services that are required to be capable of being operated under fire conditions, including their power supplies, pass through high fire risk areas, main vertical or horizontal fire zones or decks other than those which they serve, they are to be of a fire resistant type complying with 10.5.3, and:

(a) in the case of the emergency services: the fire resistant cable is to extend, at least, from the control/monitoring panel to the nearest local junction box serving the relevant deck/area; and

(b) in the case of power supplies: the fire resistant cable is to extend, at least, from the distribution point within the space containing the emergency source of electrical power to the nearest local distribution panel serving the relevant deck/area.

1.14.3 Electrical cables for the above services required to be capable of being operated under fire conditions, including their power supplies, are to be run as directly as is practicable, having regard to any special installation requirements, for example those concerning minimum bend radii.

1.14.4 In addition to 1.10.4, materials used for electrical equipment, cables and accessories within passenger accommodation areas are not to be capable of producing excessive quantities of smoke and toxic products, when tested in accordance with an acceptable and relevant Standard.

1.15 Lightning protection

1.15.1 In order to minimise the risks of damage to the craft and its electrical installation due to lightning, crafts having non-metallic masts or topmasts are to be fitted with lightning conductors in accordance with the applicable requirements of IEC 60092-401 *Electrical installations in ships. Part 401: Installation and test of completed installation* or an alternative and relevant National Standard.

1.15.2 In addition to the primary protection requirements in 1.15.1, precautions are to be taken to protect essential electronic equipment that may be susceptible to damage from voltage pulses attributable to the secondary effects of lightning. This may be achieved by suitable design and/or the use of additional protective devices, such as surge arrestors. Resultant induced voltages may be further reduced by the use of earthed metallic screened cables.

■ *Section 2* Main source of electrical power

2.1 General

2.1.1 The main source of electrical power is to comply with the requirements of this Section without recourse to the emergency source of electrical power.

2.2 Number and rating of generators and converting equipment

2.2.1 Under seagoing conditions, the number and rating of service generating sets and converting sets, such as transformers and semi-conductor converters, when any one generating set or converting set is out of action, are:

(a) to be sufficient to ensure the operation of electrical services for essential equipment and habitable conditions;
(b) to have sufficient reserve capacity to permit the starting of the largest motor without causing any motor to stall or any device to fail due to excessive voltage drop on the system;
(c) to be capable of providing the electrical services necessary to start the main propulsion machinery from a ‘dead craft condition’. The emergency source of electrical power may be used to assist if it can provide power at the same time to those services required to be supplied by Section 3, *see also* 2.3.2.

2.2.2 The arrangement of the craft’s main source of power is to be such that the operation of electrical services for essential equipment and habitable conditions can be maintained regardless of the speed and direction of the propulsion machinery shafting.

2.2.3 Where the electrical power requirement to maintain the craft in a normal operational and habitable condition is usually supplied by one generating set, arrangements are to be provided to prevent overloading of the running generator (*see* 6.9). On loss of power there is to be provision for automatic starting and connecting to the main switchboard of the standby set in as short a time as practicable, but in any case within 45 seconds, and automatic sequential restarting of essential services (*see* 1.5.1), in as short a time as practicable.

NOTE
Where the prime mover starting time will result in exceeding this starting and connection time, details are to be submitted for consideration.

2.3 Starting arrangements

2.3.1 The starting arrangements of the generating sets’ prime movers are to comply with the requirements of Pt 10, Ch 1 and 2 as applicable.

2.3.2 Where the emergency source of electrical power is required to be used to restore propulsion from a ‘dead craft condition’, the emergency generator is to be capable of providing initial starting energy for the propulsion machinery within 30 minutes of the ‘dead craft condition’. The emergency generator capacity is to be sufficient for restoring propulsion in addition to supplying those services in Section 3. *See* Pt 10, Ch 1,7.1.1 and Ch 2,6.1.1 for starting arrangements.

2.4 Prime mover governors

2.4.1 The governing accuracy of the generating sets’ prime movers is to meet the requirements of Pt 10, Ch 1 and Ch 2.

2.4.2 The maximum electrical step load switched on or off is not to cause the frequency variation of the electrical supply to exceed the parameters given in 1.7.2, *see also* Pt 10, Ch 1 and Ch 2.

2.5 Main propulsion driven generators not forming part of the main source of electrical power

2.5.1 Generators and generator systems, having the craft's propulsion machinery as their prime mover but not forming part of the craft's main source of electrical power may be used whilst the craft is at sea to supply electrical services required for normal operational and habitable conditions provided that the requirements of 2.5.2 to 2.5.4 are satisfied.

2.5.2 Within the declared operating range of the generators and/or generator system, the specified voltage and frequency variations of the Rules are to be met.

2.5.3 Where there is remote control of the propulsion machinery, arrangements are to ensure that essential machinery power supplies are maintained during manoeuvring conditions in order to prevent a blackout situation.

2.5.4 In addition to the requirements of 2.2.3, arrangements are to be fitted to automatically start one of the generators forming the main source of power should the frequency variations exceed those permitted by the Rules.

■ *Section 3* Emergency source of electrical power

3.1 General

3.1.1 The requirements of this Section apply to passenger craft, to yachts that are 500 gt or more, to cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above, and to cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 4 and 5. For other craft, *see* Section 19.

3.1.2 Passenger craft and cargo craft constructed in compliance with the HSC Code are to comply with 3.3. Other specified craft are to comply with 3.2 or 3.4 as applicable.

3.1.3 The emergency source of power for other craft will be the subject of special consideration, with due regard to the size and the intended service of the craft.

3.1.4 Where the main source of electrical power is located in two or more compartments which are not contiguous, each of which has its own self-contained systems, including power distribution and control systems, completely independent of each other and such that a fire or other casualty in any one of the spaces will not affect the power distribution from the others, or to the services required by 3.2, 3.3 or 3.4, the requirements of this Section may be considered satisfied without an additional emergency source of electrical power, provided that:

(a) there is at least one generating set of sufficient capacity to meet the requirements of 3.2, 3.3 or 3.4 in each of at least two non-contiguous spaces;
(b) the generator sets referred to in 3.1.4(a) and their self-contained systems are installed such that a source of electrical power remains available at all times to supply emergency services after damage or flooding in any one compartment.

3.1.5 Non-passenger type craft of 300 tons gross tonnage and above are to comply with 3.7.

3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more

3.2.1 A self-contained emergency source of electrical power is to be provided.

3.2.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the waterline in the final condition of damage, be operable in that condition, and be readily accessible from the open deck. They are not to be located forward of the collision bulkhead, if fitted. Consideration may also be given to alternative arrangements, such as 3.1.4, which provide an equivalent degree of safety from fire and flooding.

3.2.3 The location of:

- the emergency source of electrical power and associated transforming equipment, if any;
- the transitional source of emergency power;
- the emergency switchboard; and
- the emergency lighting switchboard;

in relation to:

- the main source of electrical power, associated transforming equipment, if any; and
- the main switchboard;

is to be such as to ensure that a fire or other casualty in spaces containing:

- the main source of electrical power, associated transforming equipment, if any, and the main switchboard; or
- in any machinery space of Category A;

will not interfere with the supply, control and distribution of emergency electrical power.

3.2.4 The space containing:

- the emergency source of electrical power, associated transforming equipment, if any;
- the transitional source of emergency electrical power; and
- the emergency switchboard;

is not to be contiguous to the boundaries of machinery spaces of Category A or those spaces containing:

- the main source of electrical power, associated transforming equipment, if any; or
- the main switchboard.

3.2.5 Where compliance with 3.2.3 or 3.2.4 is not practicable, details of the proposed arrangements are to be submitted.

3.2.6 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used exceptionally, and for short periods, to supply non-emergency circuits. Failure of the emergency switchboard when being used in other than an emergency is not to put at risk the operation of the craft or yacht.

3.2.7 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) for a period of 36 hours, emergency lighting:
   (i) at every lifeboat or liferaft preparation station, muster and embarkation station and oversides;
   (ii) in alleyways, stairways and exits, giving access to the muster and embarkation stations;
   (iii) in all service and accommodation alleyways, stairways and exits and personnel lift cars;
   (iv) in the machinery spaces, and main generating stations including their control positions;
   (v) in all control stations, machinery control rooms, and at each main and emergency switchboard;
   (vi) at the stowage positions for firemen's outfits and life saving appliances;
   (vii) at the steering gear; and
   (viii) at the fire pump, the sprinkler pump and the emergency bilge pump and at the starting position of their motors.

(b) for a period of 36 hours:
   (i) the navigation lights, and other lights as required by the International Regulations for Preventing Collisions at Sea in force; and
   (ii) the radiocommunications, as required by statutory regulations.

(c) for a period of 36 hours:
   (i) all internal communication equipment required in an emergency;
   (ii) the navigational equipment as required by statutory regulations; where such provision is unreasonable or impracticable this requirement may be waived for craft of less than 5000 tons gross;
   (iii) the fire detection, fire alarm and general alarm system, manual alarms, and the fire door holding and release system; and
   (iv) the intermittent operation of the daylight signalling lamps, the craft's whistle, the manually-operated call points and all internal signals that are required in an emergency;

   unless such services have an independent supply for the period of 36 hours from an accumulator battery, suitably located for use in an emergency;

(d) for a period of 36 hours:
   (i) emergency fire pump;
   (ii) the automatic sprinkler pump, if fitted;
   (iii) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves; and
   (iv) essential electrically powered instruments and control for propulsion machinery, if alternate sources of power are not available for such devices.

(e) for a period of 10 min:
   (i) power drives for directional control devices including those required to direct thrust forward and astern, unless there is a manual alternative complying with Pt 14, Ch 1,6.1.4, and

(f) for a period of half an hour;
   (i) any watertight doors required by Chapter 2 to be power operated together with their control, indication and alarm signals;
   (ii) the emergency arrangements to bring the lift cars to deck level for the escape of persons. The passenger lift cars may be brought to deck level sequentially in an emergency.

(g) Where applicable, the services required by 2.3.2.

3.2.8 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:

(a) Where the emergency source of electrical power is a generator it is to be:
   (i) driven by a suitable prime mover with an independent supply of fuel having a flash point (closed cup test) of not less than 43°C;
   (ii) started automatically upon failure of the electrical supply from the main source of electrical power and is to be automatically connected to the emergency switchboard; those services referred to in 3.2.7 are then to be transferred automatically to the emergency generating set. The automatic starting system and the characteristics of the prime mover are to be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 seconds; and
   (iii) provided with a transitional source of emergency electrical power according to 3.2.9.

(b) Where the emergency source of electrical power is an accumulator battery, it is to be capable of:
   (i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
   (ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and
   (iii) immediately supplying at least those services specified in 3.2.9.

3.2.9 The transitional source of emergency electrical power required by 3.2.8 may consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and so arranged as to supply automatically in the event of failure of either the main or emergency source of electrical power at least the following services, if they depend upon an electrical source for their operation:

(a) for half an hour:
   (i) the lighting required by 3.2.7(a) and (b);
   (ii) the services required by 3.2.7(c)(i), (iii) and (iv) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency;

(b) with respect to watertight doors:
   (i) power to operate the watertight doors but not necessarily simultaneously, unless an independent temporary source of stored energy is provided. The power source should have sufficient capacity to operate each door at least three times i.e. closed-open-closed, against an adverse list of 15°;
   (ii) power to the control, indication and alarm circuits for the watertight doors for half an hour.

3.2.10 The emergency switchboard is to be installed as near as is practicable to the emergency source of electrical power.

3.2.11 Where the emergency source of electrical power is a generator, the emergency switchboard is to be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

3.2.12 No accumulator battery fitted in accordance with this Section, unless for engine starting, is to be installed in the same space as the emergency switchboard. An indicator is to be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of emergency electrical power are being discharged, and provision is to be made to charge them *in situ* from a reliable on board supply.

3.2.13 The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be adequately protected at the main switchboard against overload and short circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short circuit.

3.2.14 In order to ensure the ready availability of the emergency source of electrical power to supply circuits required to provide emergency services, arrangements are to be made, where necessary, to automatically disconnect non-emergency circuits from the emergency switchboard in the event of overloading to ensure that electrical power is available to the emergency circuits.

3.2.15 Provision is to be made for the periodic testing of the complete emergency system and is to include the testing of automatic starting arrangements.

3.2.16 In addition to the emergency lighting required by 3.2.7(a) passenger craft with roll on–roll off cargo spaces or special category spaces, are to be provided with the following:

(a) in all passenger public spaces and alleyways supplementary electric lighting that can operate for at least three hours when all other sources of electric power have failed and under any condition of heel. The illumination provided is to be such that the approach to the means of escape can be readily seen. The source of power for the supplementary lighting is to consist of accumulator batteries within the lighting units that are continuously charged where practicable, from the emergency switchboard. Consideration may be given to other means of lighting which is at least as effective. The supplementary lighting is to be such that any failure of the lamp will be immediately apparent. Any accumulator battery provided is to be replaced at intervals having regard to the specified service life in the ambient conditions that they are subject to in service.

(b) A portable rechargeable battery operated lamp is to be provided in every crew space alleyway, recreational space and every working space which is normally occupied unless supplementary emergency lighting, as required by (a) is provided.

3.3 Emergency source of electrical power in craft required to comply with the HSC Code

3.3.1 The arrangements for the emergency source of electrical power are to satisfy the requirements of this sub-Section and, additionally, 3.2.1, 3.2.6, 3.2.8, 3.2.11 and 3.2.13 to 3.2.15.

3.3.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the waterline in the final condition of damage, be operable in that condition, and be readily accessible from the open deck. They are not to be located forward of the collision bulkhead, if fitted.

3.3.3 The location of:

- the emergency source of electrical power and associated transforming equipment, if any;
- the transitional source of emergency power;
- the emergency switchboard; and
- the emergency lighting switchboard;

in relation to:

- the main source of electrical power, associated transforming equipment, if any, and;
- the main switchboard;

is to be such as to ensure that a fire or other casualty in spaces containing:

- the main source of electrical power, associated transforming equipment, if any, and the main switchboard;
- or in any machinery space;

will not interfere with the supply, control and distribution of emergency electrical power.

3.3.4 The space containing:

- the emergency source of electrical power, associated transforming equipment, if any;
- the transitional source of emergency electrical power; and
- the emergency switchboard;

is not to be contiguous to the boundaries of machinery spaces and those spaces containing:

- the main source of electrical power, associated transforming equipment, if any; or
- the main switchboard.

3.3.5 Where compliance with 3.3.3 or 3.3.4 is not practicable, details of the proposed arrangements are to be submitted.

3.3.6 For passenger craft with the restrictive notation Passenger (A), the emergency source of power is to be capable of supplying simultaneously the services referred to in 3.3.7(a), 3.3.7(b) and 3.3.7(d)(ii) and (vi), for a period of 5 hours, the services referred to in 3.3.7(c) and (e) for the periods specified, and, additionally, the 'Not under command' lights for a period of 12 hours.

3.3.7 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) for a period of 12 hours, emergency lighting:
  (i) at the stowage positions of life-saving appliances and, additionally, for passenger craft at the preparation, launching and deployed positions of survival craft and equipment for embarkation into those craft;
  (ii) at all escape routes, such as alleyways, stairways, exits from accommodation and service spaces, embarkation points, etc.;
  (iii) in the passenger compartments or public spaces, if any;
  (iv) in the machinery spaces, and main emergency generating spaces including their control positions;
  (v) in control stations;
  (vi) at the stowage positions for fireman's outfits; and
  (vii) at the steering gear;
(b) for a period of 12 hours:
  (i) the navigation lights, and other lights required by the *International Regulations for Preventing Collisions at Sea* in force;
  (ii) electrical internal communication equipment for announcements during evacuation;
  (iii) fire detection and general alarm system and manual fire-alarms; and
  (iv) remote control devices of fire-extinguishing systems if electrical;
(c) for a period of four hours of intermittent operation:
  (i) the daylight signalling lamps, if they have no independent supply from their own accumulator battery; and
  (ii) the craft's whistle or siren, if electrically driven;
(d) for a period of 12 hours:
  (i) the navigational equipment as required by statutory Regulations; where such provision is unreasonable or impracticable, this requirement may be waived for craft of less than 5000 gross tonnage;
  (ii) essential electrically powered instruments and controls for propulsion machinery, if alternate sources of power are not available for such devices;
  (iii) emergency fire pump;
  (iv) the automatic sprinkler pump and drencher pump, if fitted;
  (v) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves; and
  (vi) the craft radio facilities required to be available in an emergency;
(e) for a period of 10 minutes:
  (i) power drives for directional control devices including those required to direct thrust forward and astern, unless there is a manual alternative complying with Pt 14, Ch 1,6.1.4;
(f) for Passenger (B) craft only, for a period of half an hour:
  (i) power operated sliding watertight doors together with their indicators and warning signals.
(g) for any passenger high speed craft with lifts, for a period of half an hour:
  (i) the emergency arrangements to bring the lift cars to deck level for the escape of persons. The passenger lift cars may be brought to deck level sequentially in an emergency.

3.3.8 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:

(a) Where the emergency source of electrical power is a generator it is to be:
  (i) driven by a suitable prime mover with an independent supply of fuel, having a flashpoint (closed cup test) of not less than 43° C;
  (ii) started automatically upon failure of the main source of electrical power supply unless a transitional source of emergency electrical power complying with 3.3.9 is provided; where the emergency generator is automatically started, it is to be automatically connected to the emergency switchboard; those services referred to in 3.3.9 are to be connected automatically to the emergency generator; and
  (iii) provided with a transitional source of emergency electrical power as specified in 3.3.9, except on cargo craft where it may be omitted when an emergency generator is provided capable both of supplying the services mentioned in that paragraph and of being automatically started and supplying the required load as quickly as is safe and practicable subject to a maximum of 45 seconds.
(b) Where the emergency source of electrical power is an accumulator battery it is to be capable of:
  (i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
  (ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and
  (iii) immediately supplying at least those services specified in 3.3.9.

3.3.9 The transitional source of emergency electrical power where required by 3.3.8 is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and is to be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power for at least the following services if they depend upon an electrical source for their operation:

(a) for half an hour:
  (i) the lighting required by 3.3.7(a) and (b). For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces, may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps; and

- (ii) the services required by 3.3.7(b) and (c);
- (b) with respect to watertight doors:
  - (i) power to operate the watertight doors but not necessarily simultaneously, unless an independent temporary source of stored energy is provided. The power source should have sufficient capacity to operate each door at least three times, i.e. closed-open-closed, against an adverse list of 15º; and
  - (ii) power to the control, indication and alarm circuits for the watertight doors for half an hour.

Alternatively, the above services may have independent supplies, for the period specified, from accumulator batteries suitably located for use in an emergency.

3.3.10 For passenger craft, propulsion and direction system instruments and controls power supplies are to be arranged to provide an uninterruptible supply of emergency power.

3.3.11 No accumulator battery fitted in accordance with this Section, unless for engine starting, is to be installed in the same space as the emergency switchboard. An indicator is to be mounted in a suitable place in the craft's operating compartment to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of electrical power are being discharged, and provision is to be made to charge them *in situ* from a reliable on board supply.

3.3.12 In addition to the emergency lighting required by 3.3.5(a) to (c), passenger craft with roll on-roll off spaces are to be provided with the following:

- (a) in all passenger public spaces and alleyways supplementary electric lighting that can operate for at least three hours when all other sources of electric power have failed and under any condition of heel. The illumination provided is to be such that the approach to the means of escape can be readily seen. The source of power for the supplementary lighting is to consist of accumulator batteries within the lighting units that are continuously charged, where practicable, from the emergency switchboard. Consideration may be given to other means of lighting which is at least as effective. The supplementary lighting is to be such that any failure of the lamp will be immediately apparent. Any accumulator battery provided is to be replaced at intervals having regard to the specified service life in the ambient conditions that they are subject to in service; and
- (b) a portable rechargeable battery operated lamp is to be provided in every crew space alleyway, recreational space and every working space which is normally occupied unless supplementary emergency lighting, as required by (a) is provided.

3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 4 to 6

3.4.1 The arrangements for the emergency source of electrical power are to satisfy the requirements of this sub-Section and, additionally, 3.2.1, 3.2.3, 3.2.6 and 3.2.10 to 3.2.15.

3.4.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located such that the emergency generator and the main generators together meet the requirements of 3.1.4(a) and (b).

3.4.3 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

- (a) for a period of three hours, emergency lighting at every lifeboat preparation station, muster and embarkation station and over the sides;
- (b) for a period of 12 hours, emergency lighting:
  - (i) at the stowage positions of life-saving appliances:
  - (ii) at all escape routes, such as alleyways, stairways, exits from accommodation and service spaces, embarkation points, etc.;
  - (iii) in the public spaces, if any;
  - (iv) in the machinery spaces, and main emergency generating spaces including their control positions;
  - (v) in control stations;
  - (vi) at the stowage positions for fireman's outfits;
  - (vii) at the steering gear; and
  - (viii) at the emergency fire pump, at the sprinkler pump, if any, and at the emergency bilge pump, if any, and at the starting positions of their motors;
- (c) for a period of 12 hours:
  - (i) the navigation lights, and other lights required by the *International Regulations for Preventing Collisions at Sea* in force; and
  - (ii) the radio communications, as required by statutory regulations;
- (d) for a period of 12 hours:
  - (i) electrical internal communication equipment for announcements during evacuation;
  - (ii) fire detection and general alarm system and manual fire alarms; and
  - (iii) remote control devices of fire-extinguishing systems if electrical;

  unless such services have an independent supply for a period of 12 hours from an accumulator battery, suitably located for use in an emergency;

(e) for a period of four hours of intermittent operation:
  (i) the daylight signalling lamps, if they have no independent supply from their own accumulator battery; and
  (ii) the craft's whistle or siren, if electrically driven;

(f) for a period of 12 hours:
  (i) the navigational equipment as required by statutory regulations; where such provision is unreasonable or impracticable, this requirement may be waived for craft of less than 5000 tons gross tonnage;
  (ii) essential electrically powered instruments and controls for propulsion machinery, if alternate sources of power are not available for such devices;
  (iii) emergency fire pump;
  (iv) the automatic sprinkler pump and drencher pump, if fitted; and
  (v) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves;

(g) for a period of 10 min:
  (i) power drives for directional control devices including those required to direct thrust forward and astern, unless there is a manual alternative complying with Pt 14, Ch 1,6.1.4.

(h) for a period of half an hour:
  (i) any watertight doors required by Chapter 2 to be power-operated together with their indicators and warning signals; and

(j) where applicable, the services required by 2.4.2.

3.4.4 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:

(a) Where the emergency source of electrical power is a generator it is to be:
  (i) driven by a suitable prime mover with an independent supply of fuel, having a flash point (closed cup test) of not less than 43°C;
  (ii) started automatically upon failure of the main source of electrical power supply unless a transitional source of emergency electrical power in accordance with 3.4.5 is provided; where the emergency generator is automatically started, it is to be automatically connected to the emergency switchboard; those services referred to in 3.4.5 are to be connected automatically to the emergency generator; and
  (iii) provided with a transitional source of emergency electrical power as specified in 3.4.5 unless an emergency generator is provided capable both of supplying the services mentioned in that paragraph and of being automatically started and supplying the required load as quickly as is safe and practicable subject to a maximum of 45 seconds.

(b) Where the emergency source of electrical power is an accumulator battery it is to be capable of:
  (i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
  (ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and
  (iii) immediately supplying at least those services specified in 3.4.5.

3.4.5 The transitional source of emergency electrical power where required by 3.4.4 is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and is to be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power for half an hour at least the following services if they depend upon an electrical source for their operation:

(a) the lighting required by 3.4.3(a) to (c). For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps, and

(b) all services required by 3.4.3(d)(i) to (iii) and (e) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

(c) with respect to watertight doors:
  (i) power to operate the watertight doors but not necessarily simultaneously, unless an independent temporary source of stored energy is provided. The power source should have sufficient capacity to operate each door at least three times i.e. closed-open-closed, against an adverse list of 15°;
  (ii) power to the control, indication and alarm circuits for the watertight doors for half an hour.

3.5 Starting arrangements

3.5.1 Where the emergency source of power is a generator, the starting arrangements are to comply with the requirements given in Part 10.

3.6 Prime mover governor

3.6.1 Where the emergency source of power is a generator, the governor is to comply with 2.4.

3.7 Radio installation

3.7.1 Every radio installation as required by statutory regulations is to be provided with reliable, permanently arranged electrical lighting, independent of the main and emergency sources of electrical power, for the adequate illumination of the radio controls for operating the radio installation.

3.7.2 A reserve source or sources of energy is to be provided on every craft, for the purpose of conducting distress and safety radio-communications, in the event of failure of the craft's main and emergency sources of electrical power. The reserve source or sources of energy is to be capable of simultaneously operating the VHF radio installation and, as appropriate for the sea or sea area for which the craft is equipped, either the MF radio installation, the MF/HF radio installation, or the INMARSAT 'ship to earth' station and any of the additional loads mentioned in 3.7.4, 3.7.5 and 3.7.7 for a period of at least one hour. The reserve source or sources of energy need not supply independent HF and MF radio installations at the same time.

3.7.3 The reserve source or sources of energy is to be independent of the propelling power of the craft and the craft's electrical system.

3.7.4 Where, in addition to the VHF radio installation, two or more of the other radio installations, referred to in 3.7.2, can be connected to the reserve source or sources of energy, the reserve source or sources are to be capable of simultaneously supplying, for the period specified by 3.7.2, the VHF radio installation and:

(a) all other radio installations which can be connected to the reserve source or sources of energy at the same time; or
(b) whichever of the other radio installations will consume the most power, if only one of the other radio installations can be connected to the reserve source or sources of energy at the same time as the VHF radio installation.

3.7.5 The reserve source or sources of energy may be used to supply the electrical lighting required by 3.7.1.

3.7.6 Where a reserve source of energy consists of a rechargeable accumulator battery or batteries a means of automatically charging the batteries is to be provided which is to be capable of recharging them to minimum capacity requirements within 10 hours.

3.7.7 If an uninterrupted input of information from the craft's navigational or other equipment to a radio installation as referred to in 3.7.1 is needed to ensure its proper performance, means are to be provided to ensure the continuous supply of such information in the event of failure of the craft's main or emergency source of electrical power.

■ *Section 4* External source of electrical power

4.1 Temporary external supply (shore supply)

4.1.1 Where arrangements are made for the supply of electricity from a source on shore or elsewhere, a connection box is to be installed in a position suitable for the convenient reception of flexible cables from the external source and containing a circuit-breaker or isolating switch and fuses and terminals including one earthed, of ample size and suitable shape to facilitate a satisfactory connection of three-phase external supplies with earthed neutrals.

4.1.2 Suitable cables, permanently fixed, are to be provided, connecting the terminals in the connection box to a linked switch and/or a circuit-breaker at the main switchboard. An indicator is to be provided at the main switchboard in order to show when the cables are energized.

4.1.3 Means are to be provided for checking the phase sequence of the incoming supply.

4.1.4 At the connection box a notice is to be provided giving full information on the system of supply, the normal voltage and frequency of the installation's system and the procedure for carrying out the connection.

4.1.5 Alternative arrangements may be submitted for consideration.

4.2 Permanent external supply

4.2.1 Details are to be submitted.

■ *Section 5* Supply and distribution

5.1 Systems of supply and distribution

5.1.1 The following systems of generation and distribution are acceptable:

(a) d.c., two-wire;
(b) a.c., single-phase, two-wire;
(c) a.c., three-phase;
three-wire;
four-wire with neutral solidly earthed but without hull return.

5.1.2 System voltages for both alternating current and direct current in general are not to exceed:

(a) 15 000 V for propulsion purposes;
(b) 500 V for power, cooking and heating equipment permanently connected to fixed wiring;
(c) 250 V for lighting, heaters in cabins and public rooms, and other applications not mentioned above;
(d) Voltages exceeding these will be the subject of special consideration.

5.1.3 The arrangement of the main system of supply is to be such that a fire or other casualty in any space containing the main source of electrical power, associated converting equipment, if any, the main switchboard or the main lighting switchboard will not render inoperable any emergency service, other than those located within the space where the fire or casualty has occurred.

5.1.4 The main switchboard is to be so placed relative to the main source of power that, as far as is practicable, the integrity of the main system of supply will be affected only by a fire or other casualty in one space.

5.1.5 The arrangement of the emergency system of supply is to be such that a fire or other casualty in spaces containing the emergency source of electrical power, associated converting equipment, if any, the emergency switchboard and the emergency lighting switchboard, will not cause loss of services required to maintain the propulsion and safety of the craft.

5.1.6 Distribution systems required in an emergency are to be so arranged that a fire in any main vertical zone will not interfere with the emergency distribution in any other such zone.

5.1.7 Feeders from the main and the emergency sources of electrical power are to be separated both vertically and horizontally as widely as is practicable.

5.1.8 For Passenger (A) or Passenger (B) Craft or cargo craft of 500 tons gross tonnage and over, and in any case where the total installed electrical power of the main generating sets is in excess of 3 MW or is supplied at high voltage, arrangements are to be made so that it is possible to split the switchboard, by a multipole linked circuit-breaker, disconnector or switch-disconnector, into at least two independent sections, each supplied by at least one generator.

5.1.9 Where 5.1.8 is applicable and the essential services which are duplicated are supplied from a section board, arrangements are to be made so that it is possible to split the section board into at least two independent sections each supplied by an independent section of the main switchboard either directly or through a transformer.

5.1.10 For Passenger (B) high speed craft, each part of the main busbars with its associated generators is to be arranged in separate compartments.

5.2 Essential services

5.2.1 Essential services that are required to be duplicated are to be served by individual circuits, separated in their switchboard or section board and throughout their length as widely as is practicable without the use of common feeders, protective devices, control circuits or control gear assemblies, so that any single fault will not cause the loss of both services.

5.2.2 Where 5.2.1 is applicable the main busbars of the switchboard, or section boards, are to be capable of being split, by removable links or other means, into at least two independent sections, each supplied by at least one generator, either directly or through a converter. The essential services are to be equally divided, as far as is practicable, between the independent sections.

5.2.3 Where 5.1.8 is applicable provision is to be made to transfer to a temporary circuit those essential services which are not required to be, and have not been, duplicated in the event of loss of their normal section of switchboard or section board.

5.2.4 Where the loss of the electrical supply to a particular essential service which is not duplicated would cause serious risk to the craft, it is to be fed by two independent supplies complying with 5.2.1. Such circuits are to be provided with short circuit protection and an overload and phase-failure alarm. Failure of either supply is not to cause risk to the craft during switching to the alternative supply.

5.3 Isolation and switching

5.3.1 The incoming and outgoing circuits from every switchboard or section board are to be provided with a means of isolation and switching to permit each circuit to be switched off:

(a) on load;
(b) for mechanical maintenance;
(c) in an emergency to prevent or remove danger.

Precautions are to be taken to minimise the risk of inadvertent or accidental switching.

5.3.2 Isolation and switching is to be by means of a circuit breaker or switch arranged to open and close simultaneously all insulated poles. Where a switch is used as the means of isolation and switching, it is to be capable of:

(a) switching off the circuit on load;
(b) withstanding, without damage, the overcurrents which may arise during overloads and short circuit.

In addition, these requirements do not preclude the provision of single pole control switches in final sub-circuits, for example light switches. For circuit-breakers, *see* 6.5 and 7.3.

5.3.3 Provision is to be made, in accordance with one of the following, to prevent any circuit being inadvertently energized:

(a) the circuit breaker or switch can be withdrawn, or locked in the open position;
(b) the operating handle of the circuit breaker or switch can be removed;
(c) the circuit fuses, where fitted, can be readily removed and retained by authorized personnel.

5.3.4 All lighting and power circuits installed in unattended spaces are to be controlled by multipole linked switches situated outside such spaces. Provision is to be made for the complete isolation of these circuits and locking the means of control in the off position.

5.3.5 Where a section board, distribution board or item of equipment can be supplied by more than one circuit, a switching device is to be provided to permit each incoming circuit to be isolated and the supply transferred to the alternative circuit.

5.3.6 The switching device required by 5.3.5 is to be situated within or adjacent to the section board, distribution board or item of equipment. Where necessary, interlocking arrangements are to be provided to prevent circuits being inadvertently energized.

5.3.7 A notice is to be fixed to any section board, distribution board or item of equipment to which 5.3.5 applies warning personnel before gaining access to live parts of the need to open the appropriate circuit breakers or switches, unless an interlocking arrangement is provided so that all circuits concerned are isolated before access is gained.

5.4 Insulated distribution systems

5.4.1 A device(s) is to be installed for every insulated distribution system, whether primary or secondary, for power, heating and lighting circuits, to continuously monitor the insulation level to earth and to operate an alarm in the event of an abnormally low level of insulation resistance.

5.4.2 Where any insulated lower voltage system is supplied through transformers from a high voltage system, adequate precautions are to be taken to prevent the low voltage system being charged by capacitive leakage from the high voltage system.

5.4.3 Where filters are fitted, for example to reduce EMC susceptibility, these are not to cause distribution systems to be unintentionally connected to earth.

5.5 Earthed distribution systems

5.5.1 No fuse, non-linked switch or non-linked circuit-breaker is to be inserted in an earthed conductor. Any switch or circuit-breaker fitted is to operate simultaneously in the earthed conductor and the insulated conductors. These requirements do not preclude the provision (for test purposes) of an isolating link to be used only when the other conductors are isolated.

5.5.2 For high speed craft, earthed electrical distribution systems are not to be used, with the exception of earthed intrinsically safe circuits, in areas where an explosive gas atmosphere may arise from the presence of fuel with a flash point below 43ºC (*see* Pt 15, Ch 3,3.1).

5.5.3 For high voltage systems, where the earthed neutral system of generation and primary distribution is used, earthing is to be through an impedance in order to limit the total earth fault current to a magnitude which does not exceed that of the three phase short circuit current for which the generators are designed.

5.5.4 Generator neutrals may be connected in common, provided that the third harmonic content of the voltage wave-form of each generator does not exceed five per cent.

5.5.5 Where a switchboard is split into sections operated independently or where there are separate switchboards, neutral earthing is to be provided for each section or for each switchboard. Means are to be provided to ensure that the earth connection is not removed when generators are isolated.

5.5.6 A means of isolation is to be fitted in the earthing connection of each generator so that generators can be completely isolated for maintenance.

5.5.7 All earthing impedances are to be connected to a common earth connection/bar. The connections to the common earth connection/bar are to be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, communication and control equipment circuits.

5.6 Diversity factor

5.6.1 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justified, to the application of a diversity factor. Where spare ways are provided on a section or distribution board, an allowance for future increase of load is to be added to the total connection load before application of any diversity factor.

5.6.2 A diversity factor may be applied to the calculation for size of cable and rating of switchgear and fusegear, taking into account the duty cycle of the connected loads and the frequency and duration of any motor starting loads.

5.6.3 For winches and crane motors the diversity factor is to be calculated and submitted when required.

5.7 Lighting circuits

5.7.1 Lighting circuits are to be supplied by final sub-circuits separate from those for heating and power. This does not preclude the supply from a lighting circuit supplying a single fixed appliance, such as a cabin fan, a dry shaver, a wardrobe or anti-condensation heater, taking a maximum current of 2 A. (This does not apply to cabin and wardrobe heaters).

5.7.2 Lighting for machinery spaces, control stations, normal working spaces, large galleys, corridors, stairways leading to boat decks and in public rooms is to be supplied from at least two final sub-circuits in such a way that failure of any one of the circuits does not leave the space in darkness. One of these circuits may be the emergency circuit, provided it is normally energized.

5.7.3 Lighting for enclosed hazardous spaces is to be supplied from at least two final sub-circuits to permit light from one circuit to be retained while maintenance is carried out on the other.

5.7.4 Emergency lighting is to be fitted in accordance with Section 3, *see also* Section 17.

5.8 Motor circuits

5.8.1 A separate final sub-circuit is to be provided for every motor for essential services, *see* 1.5.1.

5.9 Motor control

5.9.1 Every electric motor is to be provided with efficient means for starting and stopping so placed as to be easily operated by the person controlling the motor. Every motor above 0,5 kW is to be provided with control apparatus as given in 5.9.2 to 5.9.4.

5.9.2 Means to prevent undesired restarting after a stoppage due to low volts or complete loss of volts are to be provided. This does not apply to motors where a dangerous condition might result from the failure to restart automatically, e.g. steering gear motor.

5.9.3 Means for automatic disconnection of the supply in the event of excess current due to mechanical overloading of the motor are to be provided, *see also* 6.9.

5.9.4 Motor control gear is to be suitable for the starting current and for the full load rated current of the motor.

■ *Section 6*
System design – Protection

6.1 General

6.1.1 Installations are to be protected against overcurrents including short-circuits, and other electrical faults. The tripping/fault clearance times of the protective devices are to provide complete and co-ordinated protection to ensure:

(a) availability of essential and emergency services under fault conditions through discriminative action of the protective devices; as far as practicable the arrangements are also to secure the availability of other services;

(b) elimination of the fault to reduce damage to the system and hazard of fire.

6.1.2 Short-circuit and overload protection are to be provided in each non-earthed line of each system of supply and distribution, unless exempted under the provisions of any paragraph in this Section.

6.1.3 The protection of circuits is to be such that a fault in a circuit does not cause the interruption of supplies used to provide emergency or essential services other than those dependent on the circuit where the fault occurred. For circuits used to provide essential services which need not necessarily be in continuous operation to maintain propulsion and steering but which are necessary for maintaining the vessel's safety, arrangements that ensure that a fault in a circuit does not cause the sustained interruption of supply to healthy circuits may be accepted. Such arrangements are to ensure the supply to healthy circuits is automatically re-established in sufficient time after a fault in a circuit.

6.1.4 Protection systems are to be developed using a systematic design procedure incorporating verification and validation methods to ensure successful implementation of the requirements above. Details of the procedures used are to be submitted when requested.

6.1.5 Short-circuit protection is to be provided for each source of power and at each point at which a distribution circuit branches into two or more subsidiary circuits.

6.1.6 Where protection for generator power circuits is provided at the associated switchboard, the cabling between generator and switchboard is to be of a type, and installed in a manner such as to minimise the risk of short-circuit.

6.1.7 Protection for battery circuits is to be provided at a position external and adjacent to the battery compartments. Where arrangements comply with 11.3.5, the protection may be installed at a suitable location in the battery compartment.

6.1.8 Protection may be omitted from the following:

(a) Engine starting battery circuits.

(b) Circuits for which it can be shown that the risk resulting from spurious operation of the protective device may be greater than that resulting from a fault.

6.1.9 Short-circuit protection may be omitted from cabling or wiring to items of equipment internally protected against short-circuit or where it can be shown that they are unlikely to fail to a short-circuit condition or it is impractical for operational reasons (e.g. within battery compartments), and where the cabling or wiring is installed in a manner such as to minimise the risk of short-circuit.

6.1.10 Overload protection may be omitted from the following:

(a) one line of circuits of the insulated type;

(b) circuits supplying equipment incapable of being overloaded, or overloading the associated supply cable, under normal conditions, and unlikely to fail to an overload condition.

6.2 Protection against short-circuit

6.2.1 Protection against short-circuit currents is to be provided by circuit-breakers or fuses.

6.2.2 The rated short-circuit making and breaking capacity of every protective device is to be adequate for the prospective fault level at its point of installation; the requirements for circuit breakers and fuses are detailed in 6.4 and 6.5 respectively.

6.2.3 The prospective fault current is to be calculated for the following set of conditions:

(a) all generators, motors and, where applicable, all transformers, connected as far as permitted by any interlocking arrangements;

(b) a fault of negligible impedance close up to the load side of the protective device.

6.2.4 In the absence of precise data, the prospective fault current may be taken to be:

(a) for alternating current systems at the main switchboard: 10 x f.l.c. (rated full load current) for each generator that may be connected, or, if the subtransient direct axis reactance, X”d,of each generator is known, $\dfrac{\text{f.l.c}}{X''_d\ \text{(p.u.)}}$ for each generator and 3 x f.l.c. for motors simultaneously in service;

The value derived from the above is an approximation to the r.m.s. symmetrical fault current; the peak asymmetrical fault current may be estimated to be 2,5 times this figure (corresponding to a fault power factor of approximately 0,1).

(b) battery-fed direct current systems at the battery terminals:
   (i) 15 times ampere hour rating of the battery for vented lead-acid cells, or of alkaline type intended for discharge at low rates corresponding to a battery duration exceeding three hours, or
   (ii) 30 times ampere hour rating of the battery for sealed lead-acid cells having a capacity of 100 ampere hours or more, or of alkaline type intended for discharge at high rates corresponding to a battery duration not exceeding three hours and,
   (iii) 6 x f.l.c. for motors simultaneously in service, if applicable.

6.3 Protection against overload

6.3.1 Fuses, circuit breakers and other protective devices provided for overload protection are to have fusing/tripping characteristics ensuring the protection of cabling and electrical machinery against overheating resulting from mechanical or electrical overload.

6.3.2 Fuses of a type intended for short-circuit protection only (e.g. fuse links complying with IEC 60269-1, of type “a”) are not to be used for overload protection.

6.4 Protection against earth faults

6.4.1 Every distribution system that has an intentional connection to earth, by way of an impedance, is to be provided with a means to continuously monitor and indicate the current flowing in the earth connection.

6.4.2 If the current in the earth connection exceeds 5 A there is to be an alarm and the fault current is to be automatically interrupted or limited to a safe value.

6.4.3 The rated short circuit capacity of any device used for interrupting earth fault currents is to be not less than the prospective earth fault current at its point of installation.

6.4.4 Insulated neutral systems with harmonic distortion of the voltage waveform, which may result in earth fault currents exceeding the level given in 6.4.2 because of capacitive effects, are to be provided with arrangements to isolate the faulty circuit(s).

6.5 Circuit-breakers

6.5.1 Circuit-breakers for alternating current systems are to satisfy the following conditions:

(a) the r.m.s. symmetrical breaking current for which the device is rated is to be not less than the r.m.s. value of the a.c. component of the prospective fault current, at the first half cycle;
(b) the peak asymmetrical making current for which the device is rated is not to be less than the peak value of the prospective fault current at the first half cycle, allowing for maximum asymmetry;
(c) the power factor at which the device short circuit ratings are assigned is to be no greater than that of the prospective fault current; alternatively for high voltage, the rated percentage d.c. component of the short-circuit breaking current of the device is to be not less than that of the prospective fault current.

6.5.2 Circuit-breakers for d.c. systems are to have a breaking current not less than the initial prospective fault current. The time constant of the fault current is not to be greater than that for which the circuit-breaker was tested.

6.5.3 The fault ratings considered in 6.5.1 and 6.5.2, are to be assigned on the basis that the device is suitable for further use after fault clearance.

6.5.4 To satisfy 6.5.3, the rated service short-circuit breaking capacity of low voltage circuit-breakers:
- directly connected to main or emergency switchboard; and/or
- installed in the feeder lines for circuits used to provide essential or emergency services;

is to be not less than the prospective fault current referred to in 6.5.1(a). Low voltage circuit-breakers for other circuits may be selected on the basis of their rated ultimate short-circuit breaking capacity.

6.5.5 The rated short-time withstand current of low voltage circuit-breakers which are required to have an intentional short-time delay under short-circuit conditions to ensure discriminative action with respect to other protective devices is to be not less than the r.m.s. value of the a.c. component of the prospective fault current, at the first half cycle.

6.6 Fuses

6.6.1 Fuses for a.c. systems are to have a breaking current rating not less than the initial r.m.s. value of the a.c. component of the prospective fault current.

6.6.2 Fuses for d.c. systems are to have a d.c. breaking current rating not less than the initial value of the prospective fault current.

6.7 Circuit-breakers requiring back-up by fuse or other device

6.7.1 The use of a circuit-breaker having a short-circuit current capacity less than the prospective short-circuit current at the point of installation is permitted, provided that it is preceded by a device having at least the necessary short-circuit capacity. The generator circuit breakers are not to be used for this purpose.

6.7.2 The same device may back-up more than one circuit-breaker provided that no essential or emergency service is supplied from there, or that any such service is duplicated by arrangements unaffected by tripping of the device.

6.7.3 The combination of back-up device and circuit-breaker is to have a short circuit performance at least equal to that of a single circuit-breaker satisfying the requirements of 6.5.

6.7.4 Evidence of testing of the combination is to be submitted for consideration; alternatively, consideration may be given to arrangements where it can be shown that:

(a) the takeover current, above which the back-up device would clear a fault, is not greater than the rated short-circuit breaking capacity of the circuit-breaker and;
(b) the characteristics of the back-up device, and the prospective fault level, are such that the peak fault current rating of the circuit-breaker cannot be exceeded and;
(c) the Joule integral of the let-through current of the back-up device does not exceed that corresponding to the rated breaking current and opening time of the circuit-breaker.

6.8 Protection of generators

6.8.1 The protective gear required by 6.8.2 and 6.8.3 is to be provided as a minimum.

6.8.2 Generators not arranged to run in parallel are to be provided with a circuit-breaker arranged to open simultaneously, in the event of short-circuit, overload or under-voltage, all insulated poles. In the case of generators rated at less than 50 kW, a multiple linked switch with a fuse, complying with 5.3.2, in each insulated pole will be acceptable.

6.8.3 Generators arranged to operate in parallel are to be provided with a circuit-breaker arranged to open all insulated poles simultaneously in the event of a short-circuit, an over-load or an under-voltage. This circuit-breaker is to be provided with reverse power protection with time delay, selected or set within the limits of two per cent to 15 per cent of full load to a value fixed in accordance with the characteristics of the prime mover. A fall of 50 per cent in the applied voltage is not to render the reverse power mechanism inoperative, although it may alter the amount of reverse power required to open the breakers.

6.8.4 The generator circuit-breaker short-circuit and overload tripping arrangements, or fuse characteristics, are to be such that the machine's thermal withstand capability is not exceeded.

6.8.5 Generators having a capacity of 1500 kVA or above are to be equipped with a protective device which, in the event of a short-circuit in the generator or in the cable between the generator and its circuit breaker, will instantaneously open the circuit breaker and de-excite the generator.

6.8.6 The voltage and time delay settings of the under-voltage release mechanism(s) required by 6.8.2 and 6.8.3 are to be chosen to ensure that the discriminative action required by 6.1.1(a) is maintained.

6.9 Load management

6.9.1 Arrangements are to be made to disconnect automatically, after an appropriate time delay, circuits of the categories noted below, when the generator(s) is/are overloaded; sufficient to ensure the connected generating set(s) is/are not overloaded:

(a) non-essential circuits;
(b) circuits feeding services for habitability, *see* 1.5.2;
(c) in cargo craft, circuits for cargo refrigeration.

NOTE
For emergency generators *see* 3.2.14, with 3.3.1 or 3.4.1 where applicable.

6.9.2 If required, this load switching may be carried out in one or more stages, in which case the non-essential circuits are to be included in the first group to be disconnected.

6.9.3 An alarm is to be provided to indicate when such switching has taken place.

6.9.4 Consideration is to be given to providing means to inhibit automatically the starting of large motors, or the connection of other large loads, until sufficient generating capacity is available to supply them.

6.9.5 When the electric generating plant is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with audible and visual alarms for:

(a) Busbar voltage; high or low.
(b) Busbar frequency; low.
(c) Operating of load switching.
(d) Generator cooling air temperature high; closed air circuit machines only.

6.10 Feeder circuits

6.10.1 Isolation and protection of each feeder circuit is to be ensured by a multiple circuit-breaker or linked switch with a fuse in each insulated conductor. Protection is to be in accordance with 6.2 and 6.3. The protective devices are to allow excess current to pass during the normal accelerating period of motors.

6.11 Motor circuits

6.11.1 Motors of rating exceeding 0,5 kW and all motors for essential services are to be protected individually against overload and short circuit. For motors which for essential services are duplicated, the overload protection may be replaced by an overload alarm; arrangements for steering unit motors are to comply with 14.1.

6.11.2 Protection for both the motor and its supply cable may be provided by the same device, provided that due account is taken of any differences between ratings of cable and motor.

6.11.3 Where operation of an item of equipment is dependent upon a number of motors, consideration may be given to the provision of a common means of short-circuit protection.

6.11.4 For motors for intermittent service, the characteristics of the arrangements for overload protection are to be chosen in relation to the load factor(s) of the motor(s).

6.11.5 Where fuses are used to protect polyphase motor circuits, means are to be provided to protect the motor from unacceptable overcurrent in the case of single phasing.

6.12 Protection of transformers

6.12.1 Short circuit protection for transformers is to be provided by circuit breakers or fuses in the primary circuit and in addition, overload protection is to be provided either in the primary or secondary circuit.

6.12.2 Arrangements are to be made to prevent the primary windings of transformers being inadvertently energized from their secondary side when disconnected from their source of supply.

■ *Section 7* Switchgear and control gear assemblies

7.1 General requirements

7.1.1 Switchgear and control gear assemblies and their components are to comply with one of the following standards amended where necessary for ambient temperature and other environmental conditions:
(a) IEC 60439: *Low voltage switchgear and control gear assemblies*;
(b) IEC 62271-200*: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*;
(c) IEC 60466: *AC insulated-enclosed switchgear for rated voltages above 1 kV and up to and including 38 kV*;
(d) IEC 60255: *Electrical relays*;
(e) acceptable and relevant National Standard.
In addition, the requirements of 7.2 to 7.18 are to be complied with.

7.2 Busbars

7.2.1 Busbars and their connections are to be of copper or aluminium, all connections being so made as to inhibit corrosion/oxidation between current-carrying mating faces, which may result in poor electrical contact giving rise to overheating. Busbars and their supports are to be designed to withstand the mechanical stresses which may arise during short-circuits. A test report or calculation to verify the short-circuit withstand strength of the busbar system is to be submitted for consideration when required.

7.2.2 The maximum permissible temperature rise for bare conductors is 45°C. A test report or calculation to verify the rated current assigned to the busbar system is to be submitted for consideration when required.

7.3 Circuit-breakers

7.3.1 Circuit-breakers are to comply with one of the following standards amended where necessary for ambient temperature:
(a) IEC 60947-2: *Low voltage switchgear and Control gear Pt 2: circuit breakers*;
(b) IEC 60056: *High voltage alternating-current circuit-breakers*;
(c) acceptable and relevant National Standard.
Type test reports to verify the characteristics of a circuit-breaker are to be submitted for consideration when required.

7.3.2 Circuit-breakers are to be capable of isolation.

7.3.3 Circuit-breakers are to be of the trip free type and, where applicable, be fitted with anti-pumping control.

7.3.4 High-voltage circuit-breakers are to be of the withdrawable type or with equivalent means or arrangements permitting safe maintenance whilst the busbars are live.

7.4 Contactors

7.4.1 High-voltage contactors are to comply with one of the following standards amended where necessary for ambient temperature.
(a) IEC 60470: *High-voltage alternating current contactors*.
(b) acceptable and relevant National Standard.
Type test reports to verify the characteristics of a contactor are to be submitted for consideration when required.

7.4.2 High-voltage contactors are to be of the withdrawable type or with equivalent means or arrangements permitting safe maintenance whilst the busbars are live.

7.5 Creepage and clearance distances

7.5.1 The shortest distances between conductive parts and between conductive parts and earth in air or along the surface of an insulating material, are to be suitable for the rated voltage having regard to the nature of the insulating material and the transient over voltages developed by switching and fault conditions. This requirement may be satisfied by subjecting each assembly type to an impulse voltage test in accordance with its constructional Standard or, alternatively, maintaining the minimum distances for bare conductive parts in switchgear and control gear assemblies given in Table 2.7.1.

7.5.2 Suitable shrouding or barriers are to be provided in way of connections to equipment, where necessary, to maintain the minimum distances in Table 2.7.1.

Table 2.7.1 Minimum clearance distances

Rated voltage V	Minimum clearance (mm) between phases and earth		Minimum clearance (mm) between phases
	Earthed neutral	Insulated neutral	
≤ 660	16	19	19
1000	25	25	25
3600	55	55	55
7200	70	100	100
12000	85	140	140
15000	100	165	165

7.5.3 Creepage distances cannot be accurately specified as they depend upon the insulating material, dust deposits, humidity, etc. They are to be not less than the clearance distances given in Table 2.7.1, or less than 16 mm per 1000 V (rated voltage), whichever is the greater.

7.6 Degree of protection

7.6.1 Low voltage assemblies where the rated voltage between conductors or to earth exceeds 55 V a.c. or 250 V d.c. are to be of the deadfront or enclosed type. High-voltage assemblies are to be of the enclosed type.

7.6.2 Where switchboards or section boards are required to comply with 5.2.2, barriers are to be installed to provide protection for the independent sections against contamination due to the products of arcing, which may result in a fault.

7.7 Distribution boards

7.7.1 Distribution boards are to be suitably enclosed unless they are installed in a cupboard or compartment to which only authorized persons have access in which case the cupboard may serve as an enclosure. *See* 7.16.4.

7.8 Earthing of high-voltage switchboards

7.8.1 High-voltage switchboards are to be provided with suitable means to earth isolated circuits so that they are discharged and so maintained that they are safe to touch.

7.9 Fuses

7.9.1 Fuses are to comply with one of the following standards amended where necessary for ambient temperature.
(a) IEC 60269: *Low-voltage fuses*;
(b) IEC 60282-1: *High voltage fuses Pt 1: Current-limiting fuses*;
(c) acceptable and relevant National Standard for enclosed current-limiting fuses.

Type test reports to verify the characteristics of a fuse are to be submitted for consideration when required.

7.10 Handrail or handles

7.10.1 All main and emergency switchboards are to be provided with an insulated handrail or insulated handles suitably fitted on the front of the switchboard. Where access to the rear is required, a horizontal insulated handrail is to be suitably fitted on the rear of the switchboard.

7.11 Instruments for alternating current generators

7.11.1 For alternating current generators not operated in parallel, each generator is provided with at least one voltmeter, one frequency meter, and one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase. Generators above 50 kVA are also to be provided with a wattmeter.

7.11.2 For alternating current generators operated in parallel, each generator is to be provided with a wattmeter, and one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase.

7.11.3 For parallelling purposes, two voltmeters, two frequency meters and two synchronising devices, of which one at least is to be a synchroscope or a set of lamps are to be provided. One voltmeter and one frequency meter are to be connected to the busbars, the other voltmeter and frequency meter are to be switched to enable the voltage and frequency of any generator to be measured. Where the electrical power requirement to maintain the ship in a normal operational and habitable condition is usually supplied by two or more generators operating in parallel, the two synchronising devices are to be independent of each other (*see also* 2.2.1).

7.11.4 Where the indications of voltage, frequency, current and power are displayed digitally, the indications are to be separately displayed.

7.12 Instrument scales

7.12.1 The upper limit of the scale of every voltmeter is to be approximately 120 per cent of the nominal voltage of the circuit, and the nominal voltage is to be clearly indicated.

7.12.2 The upper limit of the scale of every ammeter is to be approximately 130 per cent of the normal rating of the circuit in which it is installed. Normal full load is to be clearly indicated.

7.12.3 Kilowatt meters for use with alternating current generators which may be operated in parallel are to be capable of indicating 15 per cent reverse power.

7.12.4 Where the indications provided by the instrumentation required by 7.11 are displayed digitally, nominal voltage, over voltage, over current and reverse power indications are to be indicated by an appropriate means. The information provided is to be clearly visible and immediately available.

7.13 Labels

7.13.1 The identification of individual circuits and their devices is to be made on labels of durable material. The ratings of fuses and settings of protective devices are also to be indicated. Section and distribution boards are to be marked with the rated voltage.

7.14 Protection

7.14.1 For details of the electrical protection required of switchgear and control gear, *see* Section 6.

7.15 Wiring

7.15.1 Insulated wiring connecting components are to be stranded, flame retardant and manufactured in accordance with a relevant and acceptable National Standard.

7.16 Position of switchboards

7.16.1 An unobstructed space not less than 1 m wide is to be provided in front of switchboards and section boards. When switchboards and section boards contain withdrawable equipment the unobstructed space is to be not less than 0,4 m wide with this equipment in its fully withdrawn position.

7.16.2 Where necessary, the space at the rear of switchboards and section boards is to be ample to permit maintenance and in general not less than 0,6 m except that this may be reduced to 0,5 m in way of stiffeners or frames.

7.16.3 The spaces defined in 7.16.1 and 7.16.2 are to have non-slip surfaces. Where access to live parts within switchboards and section boards is normally possible the surface is, in addition, to be electrically insulated.

7.16.4 So far as practicable, pipes are not to be installed directly above or in front of or behind switchboards, section boards and distribution boards. If such placing is unavoidable, suitable protection is to be provided in these positions, *see* Pt 15, Ch 2,2.4.

7.16.5 For switchgear and control gear assemblies, for rated voltages above 1 kV, arrangements are to be made to protect personnel in the event of gases or vapours escaping under pressure as the result of arcing due to an internal fault. Where personnel may be in the vicinity of the equipment when it is energised, this may be achieved by an assembly that has been tested in accordance with Annex A of IEC 62271- 200 and qualified for classification **IAC** (internal arc classification).

7.17 Switchboard auxiliary power supplies

7.17.1 Where the operation of a protective device relies upon a power supply, an alarm is to be provided to indicate failure of the power supply, unless its failure causes automatic tripping of the protected circuit.

7.18 Testing

7.18.1 Tests in accordance with 7.18.2 to 7.18.4 are to be satisfactorily carried out on all assemblies, complete or in sections, at the manufacturer's premises, and a test report issued by the manufacturer.

7.18.2 A high voltage test, *see* Section 20.

7.18.3 Calibration of protective devices and indicating instruments is to be verified by means of current and/or voltage injection.

7.18.4 Demonstration of the satisfactory operation of protection circuits, control circuits and interlocks by means of simulated functional tests.

7.18.5 For switchgear and control gear assemblies, for rated voltages above 1 kV, type tests are to be carried out, in accordance with Annex A of IEC 62271-200 and **IAC** (internal arc classification) assigned, to verify that the assembly will withstand the effects of an internal arc occurring within the enclosure at a prospective fault level equal to, or in excess of, that of the installation.

7.19 Disconnectors and switch-disconnectors

7.19.1 Disconnectors, switch-disconnectors and their components are to comply with one of the following standards, amended where necessary for ambient temperature and other environmental conditions:

(a) IEC 60947-3: *Low voltage switchgear and control gear Part 3: switches, disconnectors, switch-disconnectors and fuse combination units*.
(b) IEC 60129: *Alternating current disconnectors (isolators) and earthing switches*.
(c) Acceptable and relevant National Standard.

Type test reports to verify the characteristics of a disconnector or switch-disconnector are to be submitted for consideration when required.

■ *Section 8* Rotating machines

8.1 General requirements

8.1.1 Rotating machines are to comply with the relevant part of IEC 60092, or an acceptable and relevant National Standard, and the requirements of this Section.

8.1.2 For all the rotating machines a manufacturer's test certificate is to be provided, *see also* 1.3.

8.1.3 Shafts for rotating machines are to be forged or rolled and are to comply with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

8.1.4 Where welding is applied to shafts of machines for securing arms or spiders, stress relieving is to be carried out after welding. The finalised assembly is to be visually examined by the Surveyors, crack detection carried out by an appropriate method and the finished welds found sound and free from cracks.

8.1.5 The rotating parts of machines are to be so balanced that when running at any speed in the normal working range the vibration does not exceed the levels of IEC 60034: *Rotating electrical machines*, Part 14.

8.1.6 The lubrication arrangement for bearings are to be effective under all operating conditions including the maximum craft inclinations defined by 1.9 and there are to be effective means provided to ensure that lubricant does not reach the machine windings or other conductors and insulators.

8.1.7 Means are to be taken to prevent the ill effects of the flow of currents circulating between the shaft and machine bearings or bearings of connected machinery.

8.1.8 Alternating current machines are to be constructed such that, under any operating conditions, they are capable of withstanding the effects of a sudden short-circuit at their terminals without damage.

8.2 Rating

8.2.1 Generators, including their excitation systems, and continuously rated motors are to be suitable for continuous duty at their full rated output at maximum cooling air or water temperature for an unlimited period, without the limits of temperature rise in 8.3 being exceeded. Generators are to be capable of an overload power of not less than 10 per cent at their rated power factor for a period of 15 minutes without injurious heating. Other machines are to be rated in accordance with the duty which they have to perform and, when tested under rated load conditions, the temperature rise is not to exceed the values in 8.3.

8.2.2 When a rotating machine is connected to a supply system with harmonic distortion the rating of the machine is to allow for the increased heating effect of the harmonic loading.

8.2.3 The design and construction of smoke extraction fan motors are to be suitable for the ambient temperature and operating time required. Type test reports to verify the performance of the electric motor are to be submitted for consideration.

8.3 Temperature rise

8.3.1 The limits of temperature rise specified in Table 2.8.1, are based on the cooling air temperature and cooling water temperature given in 1.8.

8.3.2 If it is known that the temperature of cooling medium exceeds the values given in 1.8 the permissible temperature rise is to be reduced by an amount equal to the excess temperature of the cooling medium.

8.3.3 If it is known that the temperature of cooling medium will be permanently less than the values given in 1.8 the permissible temperature rise may be increased by an amount equal to the difference between the declared temperature and that given in 1.8 up to a maximum of 15°C.

8.4 Generator control

8.4.1 Each alternating current generator, unless of the self-regulating type, is to be provided with automatic means of voltage regulation; voltage build-up is not to require an external source of power. Provision is to be made to safeguard the distributing system should there be a failure of the voltage regulating system resulting in a high voltage.

8.4.2 The voltage regulation of any alternating current generator with its regulating equipment is to be such that at all loads, from zero to full load at rated power factor, the rated voltage is maintained within ±2,5 per cent under steady conditions. There is to be provision at the voltage regulator to adjust the generator no load voltage.

8.4.3 Generators, and their excitation systems, when operating at rated speed and voltage on no-load are to be capable of absorbing the suddenly switched, balanced, current demand of the largest motor or load at a power factor not greater than 0,4 with a transient voltage dip which does not exceed 15 per cent of rated voltage. The voltage is to recover to rated voltage within a time not exceeding 1,5 seconds.

8.4.4 The transient voltage rise at the terminals of a generator is not to exceed 20 per cent of rated voltage when rated kVA at a power factor not greater than 0,8 is thrown off.

8.4.5 Generators and their voltage regulation systems are to be capable of maintaining, without damage, under steady state short circuit conditions a current of at least three times the full load rated current for a duration of at least two seconds or where precise data is available for the duration of any time delay which may be provided by a tripping device for discrimination purposes.

8.4.6 Generators required to run in parallel are to be stable from no load (kW) up to the total combined full load (kW) of the group, and load sharing is to be such that the load on any generator does not normally differ from its proportionate share of the total load by more than 15 per cent of the rated output (kW) of the largest machine or 25 per cent of the rated output (kW) of the individual machine, whichever is less.

8.4.7 When generators are operated in parallel, the kVA loads of the individual generating sets are not to differ from the proportionate share of the total kVA load by more than 5 per cent of the rated kVA output of the largest machines.

Table 2.8.1 Limits of temperature rise of machines cooled by air

Limits of temperature rise of machines cooled by air, °C						
Part of machine	Method of temperature measurement	Insulation class				
		A	E	B	F	H
1. (a) a.c. windings of machines having output of 5000 kVA or more	ETD R	55 50	— —	75 70	95 90	115 110
(b) a.c. windings of machines having output of less than 5000 kVA	ETD R	55 50	— 65	80 70	100 95	115 110
2. Windings of armatures having commutators	R T	50 40	65 55	70 60	95 75	115 95
3. Field windings of a.c. and d.c. machines having d.c. excitation other than those in item 4	R T	50 40	65 55	70 60	95 75	115 95
4. (a) Field windings of synchronous machines with cylindrical rotors having d.c. excitation	R	—	—	80	100	125
(b) Stationery field windings of d.c. machines having more than one layer	R T	50 40	65 55	70 60	95 75	115 95
(c) Low resistance field windings of a.c. and d.c. machine and compensating windings of d.c. machines having more than one layer	R, T	50	65	70	90	115
(d) Single-layer windings of a.c. and d.c. machines with exposed bare or varnished metal surfaces and single-layer compensating windings of d.c. machines	R, T	55	70	80	100	125
5. Permanently short-circuited insulated windings	T	50	65	70	90	115
6. Permanently short-circuited uninsulated windings	T	The temperature rise of these parts shall in no case reach such a value that there is a risk to any insulation or other materials on adjacent parts or to the item itself				
7. Magnetic cores and other parts not in contact with windings	T					
8. Magnetic cores and other parts in contact with windings	T	50	65	70	90	110
9. Commutators and slip-rings open and enclosed	T	50	60	70	80	90

NOTES
1. Where water cooled heat exchangers are used in the machine cooling circuit the temperature rises are to be measured with respect to the temperature of the cooling water at the inlet to the heat exchanger and the temperature rises given in Table 2.8.1 shall be increased by 10°C provided the inlet water temperature does not exceed the values given in 1.8.
2. T = thermometer method
   R = resistance method
   ETD = embedded temperature detector
3. Temperature rise measurements are to use the resistance method whenever practicable.
4. The ETD method may only be used when the ETDs are located between coil sides in the slot.

8.5 Overloads

8.5.1 Machines are to withstand on test, without injury, the following momentary overloads:

(a) **Generators**. An excess current of 50 per cent for 15 seconds after attaining the temperature rise corresponding to rated load, the terminal voltage being maintained as near the rated value as possible. The forgoing does not apply to the overload torque capacity of the prime mover.

(b) **Motors**. At rated speed or, in the case of a range of speeds, at the highest and lowest speeds, under gradual increase of torque, the appropriate excess torque given below. Synchronous motors and synchronous induction motors are required to withstand the excess torque without falling out of synchronism and without adjustment of the excitation circuit preset at the value corresponding to rated load:

d.c. motors	50 per cent for 15 seconds;
polyphase a.c. synchronous motors	50 per cent for 15 seconds;
polyphase a.c. synchronous induction motors	35 per cent for 15 seconds;
polyphase a.c. induction motors	60 per cent for 15 seconds.

8.6 Machine enclosure

8.6.1 Where water cooled heat exchangers are used in the machine cooling circuit there is to be provision for the detection of water leakage and the system is to be arranged so as to prevent the entry of water into the machine.

8.6.2 An alarm is to be provided to indicate high cooling water temperature.

8.7 Direct current machines

8.7.1 The final running position of brushgear is to be clearly and permanently marked.

8.7.2 Direct current machines are to work with fixed brush setting from no load to the momentary overload specified without injurious sparking.

8.8 Survey and testing

8.8.1 On machines for essential services tests are to be carried out and a certificate furnished by the manufacturer. The tests are to include temperature rise, momentary overload, high voltage, and commutation. The insulation resistance and the temperature at which it was measured are to be recorded.

8.8.2 In the case of duplicate machines, type tests of temperature rise, excess current and torque and commutation taken on a machine identical in rating and in all other essential details may be accepted in conjunction with abbreviated tests on each machine. Type tests for propulsion machines will be specially considered. For the abbreviated tests, each machine is to be run and is to be found electrically and mechanically sound and is to have a high voltage test and insulation resistance recorded.

8.8.3 A high voltage test, in accordance with Section 20, is to be applied to new machines, preferably at the conclusion of the temperature rise test. Where both ends of each phase are brought out to accessible separate terminals each phase is to be tested separately.

8.8.4 An impulse test is to be carried out on the coils of high voltage machines in order to demonstrate a satisfactory withstand level of the inter-turn insulation to voltage surges. The test is to be carried out on all coils after they have been inserted in the slots and after wedging and bracing. Each coil shall be subjected to at least five impulses of injected voltage, the peak value of the injected voltage being given by the formula:

$$V_{peak} = 2{,}45V$$

where

V = rated line voltage r.m.s.

Alternative proposals to demonstrate the withstand level of inter-turn insulation will be considered.

■ *Section 9*
Converter equipment

9.1 Transformers

9.1.1 Paragraphs 9.1.2 to 9.1.11 apply to transformers rated for 5 kVA upwards.

9.1.2 Transformers are to comply with the requirements of IEC 60076: *Power transformers*, or an acceptable and relevant National Standard amended where necessary for ambient temperature, *see* 1.8.

9.1.3 Transformers may be of the dry type, encapsulated or liquid filled type.

9.1.4 The temperature rise of the winding of transformers above the ambient temperatures given in 1.8, when measured by resistance during continuous operation at the maximum rating, is not to exceed:

(a) For dry type transformers, air cooled:
- insulation of Class A – 50°C
- insulation of Class E – 60°C
- insulation of Class B – 70°C
- insulation of Class F – 90°C
- insulation of Class H – 110°C

(b) For liquid filled transformers:
- 50°C – where air provides cooling of the fluid
- 65°C – where water provides cooling of the fluid.

9.1.5 When a transformer is connected to a supply system with harmonic distortion, the rating of the transformer is to allow for the increased heating effect of the harmonic loading. Special attention is to be given to transformers connected for the purpose of reducing harmonic distortion.

9.1.6 The inherent regulation of transformers at their rated output is to be such that the total voltage drop to any point in the installation does not exceed that allowed by 1.7.

9.1.7 Transformers, except those for motor starting, are to be double wound.

9.1.8 Liquid fillings for transformers are to be non-toxic and of a type which does not readily support combustion. Liquid filled transformers are to have a pressure relief-device with an alarm and there is to be a suitable means provided to contain any liquid which may escape from the transformer due to the operation of the relief device or damage to the tank.

9.1.9 All transformers are to be capable of withstanding for two seconds, without damage, the thermal and mechanical effects of a short-circuit at the terminals of any winding.

9.1.10 When forced cooling is used, whether air or liquid, there is to be monitoring of the cooling medium and transformer winding temperatures with an alarm should these exceed preset limits. There are to be arrangements so that the load may be reduced to a level commensurate with the cooling available.

9.1.11 Where water cooled heat exchangers are used in transformer cooling circuits, there is to be provision for the detection of water leakage and the system is to be arranged so as to prevent the entry of water into the transformer.

9.1.12 The following tests are to be carried out on all transformers at the manufacturer's works, and a certificate of tests issued by the manufacturer:
(a) measurement of winding resistances, voltage ratio, impedance voltage, short circuit impedance, insulation resistance, load loss, no load loss and current;
(b) dielectric tests;
(c) temperature rise test on one transformer of each size and type.

9.2 Semiconductor equipment

9.2.1 The requirements of 9.2.2 to 9.2.18 apply to semiconductor equipment rated for 5 kW upwards.

9.2.2 Semiconductor equipment is to comply with the requirements of IEC 60146: *Semiconductor converters*, or an acceptable and relevant National Standard amended where necessary for ambient temperature, *see* 1.8.

9.2.3 Semiconductor static power converter equipment is to be rated for the required duty having regard to peak loads, system transients and overvoltage.

9.2.4 Converter equipment may be air or liquid cooled and is to be so arranged that it cannot remain loaded unless effective cooling is maintained. Alternatively the load may be automatically reduced to a level commensurate with the cooling available.

9.2.5 Liquid cooled converter equipment is to be provided with leakage alarms and there is to be a suitable means provided to contain any liquid which may leak from the system in order to ensure that it does not cause an electrical failure of the equipment. Where the semiconductors and other current carrying parts are in direct contact with the cooling liquid, the liquid is to be monitored for satisfactory resistivity and an alarm initiated at the relevant control station should the resistivity be outside the agreed limits.

9.2.6 Where forced cooling is used there is to be temperature monitoring of the heated cooling medium with an alarm and shutdown when the temperature exceeds a preset value.

9.2.7 Cooling fluids are to be non-toxic and of low flammability.

9.2.8 Converter equipment is to be so arranged that the semiconductor devices, fuses, control and firing circuit boards may be readily removed from the equipment for repair or replacement.

9.2.9 Test and monitoring facilities are to be provided to permit identification of control circuit faults and faulty components.

9.2.10 Protection devices fitted for convertor equipment protection are to ensure that, under fault conditions, the protective action of circuit breakers, fuses or control systems is such that there is no further damage to the convertor or the installation.

9.2.11 Converter equipment, including any associated transformers, reactors, capacitors and filters, if provided, is to be so arranged that the harmonic distortion, and voltage spikes, introduced into the craft's electrical system are within the limits of 1.7.3 or restricted to a lower level necessary to ensure that it causes no malfunction of equipment connected to the electrical installation.

9.2.12 Overvoltage spikes or oscillations caused by commutation or other phenomena, are not to result in the supply voltage waveform deviating from a superimposed equivalent sine wave by more than 10 per cent of the maximum value of the equivalent sine wave.

9.2.13 When converter equipment is operated in parallel, load sharing is to be such that under normal operating conditions overloading of any unit does not occur and the combination of paralleled equipment is stable throughout the operating range.

9.2.14 When converter equipment has parallel circuits there is to be provision to ensure that the load is distributed uniformly between the parallel paths.

9.2.15 Transformers, reactors, capacitors and other circuit devices associated with convertor equipment, or associated filters, are to be suitable for the distorted voltage and current waveforms to which they may be subjected and filter circuits are to be provided with facilities to ensure that their capacitors are discharged before the circuits are energized.

9.2.16 Any regenerated power developed during the operation of converter equipment is not to result in disturbances to the supply system voltage and frequency which exceeds the limits of 1.7.

9.2.17 Where control systems form an integral part of semiconductor equipment, they are to be designed and manufactured with regard to the environmental conditions to which they will be exposed in service and their performance is to be demonstrated during the test and trials programme.

9.2.18 Tests at the manufacturer's works of converter equipment and any associated reactors or filters are to include the high voltage test of 20.1, a temperature rise test, on one of each size and type of converter equipment, and such other tests as may be necessary to demonstrate the suitability of the equipment for its intended duty. Details of tests are to be submitted for consideration when required, *see also* 1.3.2.

9.3 Uninterruptible power systems

9.3.1 Where uninterruptible power systems (UPS) are required to maintain essential services or provide emergency services, the requirements of this Sub-Section apply. This Sub-Section is in addition to the requirements of 9.1 and 9.2 and Section 11, as applicable.

9.3.2 UPS units are to be constructed in accordance with IEC 62040: *Uninterruptible power systems (UPS)*, or an acceptable and relevant National or International Standard.

9.3.3 The operation of a UPS is not to depend upon external services.

9.3.4 The type of UPS unit employed, whether off-line, line-interactive or on-line, is to be appropriate to the power supply requirements of the connected load equipment.

9.3.5 An external bypass, that is hardwired and manually operated, is to be provided for UPS to allow isolation of UPS for safety during maintenance and maintain continuity of load power.

9.3.6 UPS units are to be monitored and an audible and visual alarm is to be initiated in the navigating bridge or the engine control room, or an equivalent attended location for:

- power supply failure (voltage and frequency) to the connected load;
- earth fault;
- operation of battery protective device;
- battery discharge; and
- bypass in operation for on-line UPS units.

9.3.7 UPS units required to provide emergency services are to be suitably located for use in an emergency.

9.3.8 UPS units utilising valve-regulated sealed batteries may be located in compartments with standard marine or industrial electrical equipment provided that the arrangements comply with 11.3.5. Ventilation arrangements in accordance with IEC 62040: *Uninterruptible power systems (UPS),* or an acceptable and relevant National or International Standard, may be considered to satisfy the requirements of 11.5.10.

9.3.9 Output power is to be maintained for the duration required for the connected equipment.

9.3.10 The UPS battery capacity is, at all times, to be capable of supplying the designated loads for the time specified. Where it is proposed that additional circuits are connected to the UPS unit, details verifying that the UPS unit has adequate capacity are to be submitted for consideration, *see* 1.4.

9.3.11 On restoration of the input power, the rating of the charge unit is to be sufficient to recharge the batteries while maintaining the output supply to the load equipment.

9.3.12 Tests at the manufacturer's works are to include such tests necessary to demonstrate the suitability of a UPS unit for its intended duty and location. This is expected to include as a minimum the following tests:

- a temperature rise test and battery capacity test on one of each size and type of UPS;
- the high voltage test of 20.1;
- a ventilation rate test; and
- functional testing, including operation of alarms.

Details of tests are to be submitted for consideration when required, *see also* 1.3.2.

9.3.13 Where the supply is to be maintained without a break following a power input failure, this is to be verified after installation by practical testing.

■ *Section 10* Electrical cables and busbar trunking systems (busways)

10.1 General

10.1.1 The requirements of 10.1 to 10.15 apply to all electric cables for fixed wiring unless otherwise exempted. The requirements of 10.16 apply to busbar trunking systems (busways) where they are used in place of electric cables.

10.1.2 Electric cables for fixed wiring are to be designed, manufactured and tested in accordance with the relevant IEC Standard stated in Table 2.10.1 or an acceptable and relevant National Standard.

Table 2.10.1 Electric cables

Application	IEC Standard	Title
General constructional and testing requirements	60092–350	Low-voltage shipboard power cables. General construction and test requirements
Fixed power and control circuits	60092–353	Single and multicore non-radial field power cables with extruded solid insulation for rated voltages 1kV and 3kV
Fixed power circuits	60092–354	Single and three-core power cables with extruded solid insulation for rated voltages 6kV, 10kV and 15kV
Instrumentation, control and communication circuits up to 60 V	60092–375	Shipboard telecommunication cables and radio frequency cables – General instrumentation, control and communication cables
Control circuits up to 250 V	60092–376	Shipboard multicore cables for control circuits
Mineral insulated	60702	Mineral insulated cables with a rated voltage not exceeding 750 V

10.1.3 Provided that adequate flexibility of the finished cable is assured, conductors of nominal cross-section area 2,5 mm^2 and less need not be stranded.

10.1.4 Electric cables for non-fixed wiring applications are to comply with an acceptable and relevant standard.

10.1.5 For the purpose of this Section, pipes, conduits, trunking or any other system for the additional mechanical protection of cables are hereafter referred to under the generic name ‘protective casings’.

10.2 Testing

10.2.1 Routine tests, consisting of at least:

(a) measurement of electrical resistance of conductors;

(b) high voltage test (*see also* Section 20);

(c) insulation resistance measurement;

(d) for high voltage cables, partial discharge tests are to be made in accordance with the requirements of the relevant publication or National Standard referred to in 10.1.2 at the manufacturer's works prior to despatch.

Evidence of successful completion of routine tests is to be provided by the manufacturer.

10.2.2 Particular, special and type tests are to be made, when required, in accordance with the requirements of the relevant publication or National Standard referred to in 10.1.2 and a test report issued by the manufacturer.

10.3 Voltage rating

10.3.1 The rated voltage of any electric cable is to be not lower than the nominal voltage of the circuit for which it is used. The maximum sustained voltage of the circuit is not to exceed the maximum voltage for which the cable has been designed.

10.3.2 Electric cables used in unearthed systems are to be suitably rated to withstand the additional stresses imposed on the insulation due to an earth fault.

10.4 Operating temperature

10.4.1 The maximum rated conductor temperature of the insulating material for normal operation is to be at least 10°C higher than the maximum ambient temperature liable to be produced in the space where the cable is installed.

10.4.2 The maximum rated conductor temperatures for normal and short-circuit operation, for the insulating materials included within the standards referred to in 10.1.2 is not to exceed the values stated in Table 2.10.2.

10.4.3 Electric cables constructed of an insulating material not included in Table 2.10.2 are to be rated in accordance with the National Standard chosen in compliance with 10.1.2.

10.5 Construction

10.5.1 Electric cables are to be at least of a flame-retardant type. Compliance with IEC 60332-1-2: *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1kW pre-mixed flame*, will be acceptable.

10.5.2 Exemption from the requirements of 10.5.1 for applications such as radio frequency or digital communication systems, which require the use of particular types of cable, will be subject to special consideration.

Table 2.10.2 Maximum rated conductor temperature

Type of Insulating compound	Maximum rated conductor temperature °C	
	Normal Operation	Short Circuit
Thermoplastics :		
• Based upon polyvinyl chloride or co-polymer of vinyl chloride and vinyl acetate	60	150
• Based upon Polyethylene	60	130
Elastomeric or thermosettings :		
• Based upon ethylene propylene rubber or similar (EPM or EPDM)	85	250
• Based upon Chemically crosslinked polyethylene	85	250
• Based upon silicon rubber	95	To be submitted
Mineral	95	To be submitted

10.5.3 Where electric cables are required to be of a 'fire resistant type', they are in addition to be easily distinguishable and to comply with the performance requirements of the appropriate part of IEC 60331:*Tests for electric cables under fire conditions - Circuit integrity*, when tested with a minimum flame application time of 90 minutes, as follows:

IEC 60331-21*: Procedures and requirements – Cables of rated voltage up to and including 0.6/1.0kV;*

IEC 60331-23: *Procedures and requirements – Electric data cables;*

IEC 60331-25: *Procedures and requirements – Optical fibre cables; or*

IEC 60331-31: *Procedures and requirements – Cables of rated voltage up to and including 0.6/1.0kV,* where the overall diameter of the cable exceeds 20mm.

10.5.4 Where electric cables are installed in locations exposed to the weather, in damp and in wet situations, in machinery compartments, refrigerated spaces or exposed to harmful vapours including oil vapour they are to have the conductor insulating materials enclosed in an impervious sheath of material appropriate to the expected ambient conditions.

10.5.5 Electric cables where it is required that their construction includes metallic sheaths, armouring or braids are to be provided with an overall impervious sheath or other means to protect the metallic elements against corrosion.

10.5.6 Where single core electric cables are used in circuits rated in excess of 20 Amps and are armoured the armour is to be of a non-magnetic material.

10.5.7 Electric cables are to be constructed such that they are capable of withstanding the mechanical and thermal effects of the maximum short-circuit current which can flow in any part of the circuit in which they are installed, taking into consideration not only the time/current characteristics of the circuit protective device but also the peak value of the prospective short-circuit current. Where electric cables are to be used in circuits with a maximum short circuit current in excess of 70 kA, evidence is to be submitted for consideration when required demonstrating that the cable construction can withstand the effects of the short circuit current.

10.5.8 All high voltage electric cables are to be readily identified by suitable marking.

10.6 Conductor size

10.6.1 The maximum continuous load carried by a cable is not to exceed its continuous current rating. It is to be chosen such that the maximum rated conductor temperature for normal operation for the insulation is not exceeded. In assessing the current rating the correction factors in 10.7 may be applied as required.

10.6.2 The cross-sectional area of the conductors is to be sufficient to ensure that, under short-circuit conditions, the maximum rated conductor temperature for short-circuit operation is not exceeded, taking into consideration the time current characteristics of the circuit protective device and the peak value of the prospective short-circuit current.

10.6.3 The cable current ratings given in Tables 2.10.3 and 2.10.4 are based on the maximum rated conductor temperatures given in Table 2.10.2. When cable sizes are selected on the basis of precise evaluation of current rating based upon experimental and calculated data, details are to be submitted for consideration. Alternative short-circuit temperature limits, other than those given in Table 2.10.4, may be applied using the data provided in:

- IEC 60724: *Short-circuit temperature limits of electric cables with rated voltages of 1kV (Um=1,2kV) and 3kV (Um=3,6kV)*; or
- IEC 60986: *Short-circuit temperature limits of electric cables with rated voltages from 6kV (Um=7,2kV) and up to 30kV (Um=36kV)*.

Alternative short-circuit temperature limits provided in an acceptable and relevant National Standard may also be considered.

10.6.4 The cross-sectional area of the conductors is to be sufficient to ensure that at no point in the installation will the voltage variations stated in 1.7 be exceeded when the conductors are carrying the maximum current under their normal conditions of service.

10.6.5 The size of earth conductors is to comply with 1.11.7.

10.6.6 The cross-sectional area of conductors used in circuits supplying cyclic or non-continuous loads is to be sufficient to ensure that the cable's maximum rated conductor temperature for normal operation is not exceeded when the conductors are operating under their normal conditions of service, *see* 10.7.4.

10.7 Correction factors for cable current rating

10.7.1 The correction factors of 10.7.2 to 10.7.5 provide a guide for general applications in assessing a current rating. A more precise evaluation based upon experimental and calculated data may be submitted for consideration.

10.7.2 Bunching of cables. Where more than six electric cables, which may be expected to operate simultaneously at their full rated capacity, are laid close together in a cable bunch in such a way that there is an absence of free air circulation around them, a correction factor of 0,85 is to be applied. Signal cables may be exempted from this requirement.

10.7.3 Ambient temperature. The current ratings of Table 2.10.3 are based on an ambient temperature of 45°C. For other values of ambient temperature the correction factors shown in Table 2.10.5 are to be applied.

10.7.4 Short time duty. When the load is not continuous i.e. operates for periods of half an hour or one hour and the periods of no load are longer than three times the cable's time constant T in minutes, the cable's continuous rating may be increased by a duty factor, calculated in accordance with:

$$\text{Duty factor} = \sqrt{\frac{1{,}12}{1 - e^{\frac{-t_s}{T}}}}$$

When the load is not continuous, is repetitive and has periods of no-loads less than three times the cable's time constant, so that the cable has insufficient time to cool down between the applications of load, the cable's continuous rating may be increased by an intermittent factor, calculated in accordance with:

$$\text{Intermittent factor} = \sqrt{\frac{1 - e^{\frac{-t_p}{T}}}{1 - e^{\frac{-t_s}{T}}}}$$

where

T = $0{,}245d^{1{,}35}$ where d is the overall diameter of the cable, in mm

t_s = the service time of the load current, in minutes

t_p = the intermittent period in minutes, i.e. the total period of load and no-load before the cycle is repeated.

10.7.5 Diversity. Where cables are used to supply two or more final sub-circuits account may be taken of any diversity factors which may apply, *see* 5.6.

10.8 Installation of electric cables

10.8.1 Electric cable runs are to be as far as practicable fixed in straight lines and in accessible positions.

10.8.2 Bends in fixed electric cable runs are to be in accordance with the cable manufacturer's recommendations. The minimum internal radius of bend for the installation of fixed electric cables is to be chosen according to the construction and size of the cable and is not to be less than the values given in Table 2.10.6.

Table 2.10.3 Electric cable current ratings, normal operation, based on ambient 45°C

Nominal cross section	Continuous r.m.s current rating, in amperes								
	Thermoplastic, PVC, PE			EP rubber and crosslinked PE			Silicon rubber or mineral		
	single core	2 core	3 or 4 core	single core	2 core	3 or 4 core	single core	2 core	3 or 4 core
0,75	6	5	4	13	11	9	17	14	12
1	8	7	6	16	14	11	20	17	14
1,25	10	8	7	18	15	13	23	19	16
1,5	12	10	8	20	17	14	24	20	17
2	13	11	9	25	21	17	31	26	21
2,5	17	14	12	28	24	20	32	27	22
3,5	21	18	14	35	30	24	39	33	27
4	22	19	15	38	32	27	42	36	29
5,5	27	23	19	46	39	32	52	44	36
6	29	26	20	48	41	34	55	47	39
8	35	30	24	59	50	41	66	56	46
10	40	34	28	67	57	47	75	64	53
14	49	42	34	83	71	58	94	80	66
16	54	46	38	90	77	63	100	85	70
22	66	56	46	110	93	77	124	105	87
25	71	60	50	120	102	84	135	115	95
30	80	68	56	135	115	94	151	128	106
35	87	74	61	145	123	102	165	140	116
38	92	78	64	155	132	108	175	149	122
50	105	89	74	185	153	126	200	175	140
60	123	104	86	205	174	143	233	198	163
70	135	115	95	225	191	158	255	217	179
80	147	125	103	245	208	171	278	236	195
95	165	140	116	275	234	193	310	264	217
100	169	144	118	285	242	199	320	272	224
120	190	162	133	320	272	224	360	306	252
125	194	165	134	325	280	230	368	313	258
150	220	187	154	365	310	256	410	349	287
185	250	213	175	415	353	291	470	400	329
200	260	221	182	440	375	305	494	420	346
240	290	247	203	490	417	343	570	485	400
300	335	285	235	560	476	392	660	560	460

10.8.3 The installation of electric cables across expansion joints in any structure is to be avoided. Where this is not practicable, a loop of electric cable of length sufficient to accommodate the expansion of the joint is to be provided. The internal radius of the loop is to be at least 12 times the external diameter of the cable.

10.8.4 Electric cables for essential and emergency services are to be arranged, so far as is practicable, to avoid galleys, machinery spaces and other enclosed spaces and areas of high fire risk except as is necessary for the service being supplied. Such cables are also, so far as reasonably practicable, to be routed clear of bulkheads to preclude their being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.

10.8.5 Electric cables having insulating materials with different maximum rated conductor temperatures are to be so installed that the maximum rated conductor temperature for normal operation of each cable is not exceeded.

10.8.6 Electric cables having a protective covering which may damage the covering of other cables are not to be bunched with those other cables.

10.8.7 Electric cables are to be as far as practicable installed remote from sources of heat. Where installation of cables near sources of heat cannot be avoided and where there is consequently a risk of damage to the cables by heat, suitable shields, insulation or other precautions are to be installed between the cables and the heat source. The free air circulation around the cables is not to be impaired.

Table 2.10.4 Electric cable current ratings, r.m.s. short circuit current

Nominal cross section	Fault current at 250°C duration			Fault current at 150°C duration			Fault current at 130°C duration		
	1,0 sec. kA	0,5 sec. kA	0,1 sec. kA	1,0 sec. kA	0,5 sec. kA	0,1 sec. kA	1,0 sec. kA	0,5 sec. kA	0,1 sec. kA
1	0,1	0,2	0,5	0,1	0,2	0,4	0,1	0,2	0,3
1,5	0,2	0,3	0,7	0,2	0,3	0,5	0,2	0,3	0,5
2,5	0,4	0,5	1,1	0,3	0,4	0,9	0,3	0,4	0,8
4	0,6	0,8	1,8	0,5	0,7	1,5	0,4	0,6	1,3
6	0,9	1,2	2,8	0,7	1,0	2,2	0,6	0,9	2,0
10	1,5	2,1	4,6	1,2	1,6	3,7	1,0	1,5	3,3
16	2,3	3,3	7,4	1,9	2,6	5,9	1,7	2,4	5,3
25	3,6	5,2	12	2,9	4,1	9,2	2,6	3,7	8,2
35	5,1	7,2	16	4,1	5,8	13	3,6	5,2	12
50	7,3	10	23	5,8	8,2	18	5,2	7,4	16
70	10	14	32	8,2	12	26	7,3	10	23
95	14	20	44	11	16	35	9,9	14	31
120	17	25	55	14	20	44	13	18	40
150	22	31	69	17	25	55	16	22	49
185	27	38	85	22	31	68	19	27	61
240	35	49	110	28	40	89	25	35	79
300	44	62	140	35	50	110	31	44	100

Table 2.10.5 Correction factors

Insulation material	Correction factor for ambient air temperature of °C										
	35	40	45	50	55	60	65	70	75	80	85
PVC, Polyethylene	1,29	1,15	1,00	0,82	—	—	—	—	—	—	—
EPR, XLPE	1,12	1,06	1,00	0,94	0,87	0,79	0,71	0,61	0,50	—	—
Mineral, Silicon rubber	1,10	1,05	1,00	0,95	0,89	0,84	0,77	0,71	0,63	0.55	0,45

Table 2.10.6 Minimum internal radii of bends in cables for fixed wiring

Cable construction		Overall diameter of cable	Minimum internal radius of bend (times overall diameter of cable)
Insulation	Outer covering		
Thermoplastic and elastomeric 600/1000 V and below	Metal sheathed Armoured and braided	Any	6*D*
	Other finishes	≤ 25 mm > 25 mm	4*D* 6*D*
Mineral	Hard metal sheathed	Any	6*D*
Thermoplastic and elastomeric above 600/1000 V – single core	Any	Any	12*D*
– multicore	Any	Any	9*D*

10.8.8 Where electric cables are installed in bunches, provision is to be made to limit the propagation of fire. This requirement is considered satisfied when cables of the bunch have been tested in accordance with the requirements of IEC 60332:*Tests on electric cables under fire conditions, Part 3-22, Test for vertical flame spread of vertically-mounted bunched wires or cables – Category A*, and are installed in the same configuration(s) as are used for the test(s). If the cables are not so installed, information is to be submitted to satisfactorily demonstrate that suitable measures have been taken to ensure that an equivalent limit of fire propagation will be achieved for the configurations to be used. Particular attention is to be given to cables in:

- atria or equivalent spaces; and
- vertical runs in trunks and other restricted spaces.

In addition, cables that comply with the requirements of IEC 60332-3-22 are also required to meet the requirements of IEC 60332-1-2.

10.8.9 Electric cables are not to be coated or painted with materials which may adversely affect their sheath or their fire performance.

10.8.10 Where electric cables are installed in refrigerated spaces they are not to be covered with thermal insulation but may be placed directly on the face of the refrigeration chamber, provided that precautions are taken to prevent the electric cables being used as casual means of suspension.

10.8.11 All metal coverings of electric cables are to be earthed in accordance with 1.11.

10.8.12 High voltage cables may be installed as follows:

(a) in the open, e.g. on carrier plating, when they are to be provided with a continuous metallic sheath or armour which is effectively bonded to earth to reduce danger to personnel. The metallic sheath or armour may be omitted provided that the cable sheathing material has a longitudinal electric resistance high enough to prevent sheath currents which may be hazardous to personnel;

(b) contained in earthed metallic protective casings when the cables may be as in (a) or the armour or metal sheath may be omitted. In the latter case care is to be taken to ensure that protective casings are electrically continuous and that short lengths of cable are not left unprotected.

10.8.13 High voltage electric cables are not to be run in the open through accommodation spaces.

10.8.14 High voltage electric cables are to be segregated as far as is practicable from electric cables operating at lower voltages.

10.8.15 a.c. wiring is to be carried out using multicore cables wherever reasonably practicable. Where it is necessary to install single core electric cables for alternating current circuits in excess of 20 Amps the requirements of 10.13 are to be complied with, *see also* 10.5.6.

10.9 Mechanical protection of cables

10.9.1 Electric cables are to be, so far as reasonably practicable, installed remote from sources of mechanical damage. Where electric cables are exposed to risk of mechanical damage they are to be protected by suitable protective casings unless the protective covering (e.g. armour or sheath) is sufficient to withstand the possible cause of damage.

10.9.2 Electric cables installed in spaces where there is exceptional risk of mechanical damage such as holds, storage spaces, cargo spaces, etc., are to be suitably protected by metallic protective casings, even when armoured, unless the craft's structure affords adequate protection.

10.9.3 Non-metallic protective casings and fixings are to be flame retardant in accordance with the requirements of IEC 60092-101.

10.9.4 Metal protective casings are to be efficiently protected against corrosion, and effectively earthed in accordance with 1.11.

10.10 Cable support systems

10.10.1 Electric cables are to be effectively supported and secured, without being damaged, to the craft's structure, either indirectly by a cable support system, or directly by means of clips, saddles or straps to bulkheads, etc., *see* 10.8.4.

10.10.2 Cable support systems, which may be in the form of trays or plates, separate support brackets, hangers or ladder racks, together with their fixings and accessories, are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection. Where cable support systems are manufactured of plastics materials, evidence of satisfactory type testing in accordance with an acceptable test procedure is to be submitted for consideration. The cable support system is to be effectively secured to the craft's structure, the spacing of the fixings taking account of the probability of vibration and any heavy external forces, e.g. where located in areas subject to impact by sea-water.

10.10.3 The distances between the points at which the cable is supported (e.g. distances between ladder rungs, support brackets, hangers, etc.) are to be chosen according to the construction of cable (i.e. size and rigidity) and the probability of vibration and are to be generally in accordance with those given in Table 2.10.7.

10.10.4 Where the cables are laid on top of their support system, the spacings of fixings may be increased beyond those given in Table 2.10.7, but should take account of the probability of movement and vibration and in general is not to exceed 900 mm. This relaxation is not to be applied where cables can be subjected to heavy external forces, e.g. where they are run on, or above, open deck or in areas subject to impact by sea-water.

Table 2.10.7 Maximum spacing of supports or fixings for securing cables

External diameter of cable		Non-armoured cables	Armoured cables
Exceeding	Not exceeding		
mm	mm	mm	mm
—	8	200	250
8	13	250	300
13	20	300	350
20	30	350	400
30	—	400	450

10.10.5 Where the cable support system or fixings are manufactured from a material other than metal, suitable supplementary metallic fixings or straps spaced at regular distances are to be provided, such that, in the event of a fire or failure, the cable support system and the cables affixed to it are prevented from falling and causing an injury to personnel and/or an obstruction to any escape route. Alternatively, the cables may be routed away from such areas.

10.10.6 Cable support systems manufactured of plastics materials installed on the open deck are to be protected from degradation caused by exposure to solar radiation.

10.10.7 Single core electric cables are to be firmly fixed, using supports of strength adequate to withstand forces corresponding to the values of the peak prospective short-circuit current.

10.11 Penetration of bulkheads and decks by cables

10.11.1 Where electric cables pass through watertight, fire insulated or gas tight bulkheads, the arrangements are to be such as to ensure the integrity of the bulkhead or deck is not impaired. The arrangements chosen are to ensure that the cables are not adversely affected.

10.11.2 Where cables pass through non-watertight bulkheads or structural steel, the holes are to be bushed with suitable material. If the steel is at least 6 mm thick, adequately rounded edges may be accepted as the equivalent of bushing.

10.11.3 Electric cables passing through decks are to be protected by deck tubes or ducts.

10.11.4 Where cables pass through thermal insulation they are to do so at right angles, in tubes sealed at both ends.

10.12 Installation of electric cables in protective casings

10.12.1 Protective casings are to be mechanically continuous across joints and effectively supported and secured to prevent damage to the electric cables.

10.12.2 When protective casings are secured by means of clips or straps manufactured from a material other than metal the fixings are to be supplemented by suitable metal clips or straps spaced at regular distances each not exceeding 2 m.

10.12.3 Protective casings are to be suitably smooth on the interior and have their ends shaped or bushed in such a manner as not to damage the cables.

10.12.4 The internal radius of bends of protective casings are to be not less than that required for the largest cable installed therein, *see* 10.8.2.

10.12.5 The space factor (ratio of the sum of the cross sectional areas corresponding to the external diameters of the cables to the internal cross sectional area of the protective casings) is not to exceed 0,4.

10.12.6 Where necessary, ventilation openings are to be provided at the highest and lowest points of protective casings to permit air circulation and to prevent accumulation of water.

10.12.7 Expansion joints are to be provided in protective casings where necessary.

10.12.8 Protective casings containing high voltage electric cables are not to contain other electric cables and are to be clearly identified, defining their function and voltage.

10.13 Single core electric cables for alternating current

10.13.1 When installed in protective casings, electric cables belonging to the same circuit are to be installed in the same casing, unless the casing is of non-magnetic material.

10.13.2 Cable clips are to include electric cables of all phases of a circuit unless the clips are of non-magnetic material.

10.13.3 Single-core cables of the same circuit are to be in contact with one another, as far as possible. In any event the distance between adjacent electric cables is not to be greater than one cable diameter.

10.13.4 If single-core cables of current rating greater than 250 A are installed near a steel bulkhead, the clearance between the cables and the bulkhead is to be at least 50 mm unless the cables belonging to the same a.c. circuit are installed in trefoil formation.

10.13.5 Magnetic material is not to be used between single core cables of a group. Where cables pass through steel plates, all the conductors of the same circuit are to pass through a plate or gland, so made that there is no magnetic material between the cables, and the clearance between the cables and the magnetic material is not to be less than 75 mm, unless the cables belonging to the same a.c. circuit are installed in trefoil formation.

10.13.6 Electric cables are to be installed such that the induced voltages, and any circulating currents, in the sheath or armour are limited to safe values.

10.14 Electric cable ends

10.14.1 Where screw-clamp or spring-clamp type terminations are used in electrical apparatus for external cable connections (*see* 1.10.6), cable conductors of the solid or stranded type may be inserted directly into the terminals. Where flexible conductors are used, a suitable termination is to be fitted to the cable conductor to prevent 'whiskering' of the strands.

10.14.2 If compression type conductor terminations are used on the cable ends, they are to be of a size to match the conductor and to be made with a compression type tool with the dies selected to suit the termination and conductor sizes and having a ratchet action to ensure completion of the compression action.

10.14.3 Soldered sockets may be used in conjunction with non-corrosive fluxes provided that the maximum conductor temperature at the joint, under short circuit conditions, does not exceed 160°C.

10.14.4 High voltage cables of the radial field type, i.e. having a conducting layer to control the electric field within the insulation, are to have terminations which provide electrical stress control.

10.14.5 Electric cables having hygroscopic insulation (e.g. mineral insulated) are to have their ends sealed against ingress of moisture.

10.14.6 Cable terminations are to be of such a design and dimensions that the maximum current likely to flow through them will not result in degradation of the contacts or damage to insulation as the result of overheating.

10.14.7 The fixing of conductors in terminals at joints and at tappings is to be capable of withstanding the thermal and mechanical effects of short circuit currents.

10.15 Joints and branch circuits in cable systems

10.15.1 If a joint is necessary it is to be carried out so that all conductors are adequately secured, insulated and protected from atmospheric action. The flame retardant properties or fire resisting properties of the cable are to be retained, the continuity of metallic sheath, braid or armour is to be maintained and the current carrying capacity of the cable is not to be impaired.

10.15.2 Tappings (branch circuits) are to be made in suitable boxes of such a design that the conductors remain suitably insulated, protected from atmospheric action and fitted with terminals or busbars of dimensions appropriate to the current rating.

10.16 Busbar trunking systems (bustrunks)

10.16.1 Where busbar trunking systems are used in place of electric cables, they are to comply with the requirements of 10.16.2 to 10.16.6, in addition to the applicable requirements in Section 7.

10.16.2 The busbar trunking, or enclosure system, is to have a minimum ingress protection of IP54, according to IEC60529: *Degrees of protection provided by enclosures* (IP Code).

10.16.3 The internal and external arrangements of the busbar trunking, or enclosure system, are to ensure that the fire and/or watertight integrity of any structure through which it passes is not impaired.

10.16.4 Where the busbar trunking system is employed for circuits on and below the bulkhead deck, arrangements are to be made to ensure that circuits on other decks are not affected in the event of partial flooding under the normal angles of inclination given in 1.9 for essential electrical equipment.

10.16.5 Supports and accessories are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection. The support system is to effectively secure the busbar trunking system to the craft's structure.

10.16.6 When accessories are fixed to the busbar system by means of clips or straps manufactured from a material other than metal, the fixings are to be supplemented by suitable metal clips or straps, such that, in the event of a fire or failure, the accessories are prevented from falling and causing injury to personnel and/or an obstruction to any escape route. Alternatively, the busbar system may be routed away from such areas.

■ *Section 11* **Batteries**

11.1 General

11.1.1 The requirements of this Section apply to permanently installed secondary batteries of the vented and valve-regulated sealed type.

11.1.2 A vented battery is one in which the cells have a cover provided with an opening through which the products of electrolysis and evaporation are allowed to escape freely from the cells to the atmosphere.

11.1.3 A valve-regulated sealed battery is one in which the cells are closed but have an arrangement (valve) which allows the escape of gas if the internal pressure exceeds a predetermined value. The electrolyte cannot normally be replaced.

11.2 Construction

11.2.1 Batteries are to be constructed so as to prevent spilling of the electrolyte due to motion and to minimise the emission of electrolyte spray.

11.3 Location

11.3.1 Vented batteries connected to a charging device with a power output of more than 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, are to be housed in an adequately ventilated compartment assigned to batteries only, or in an adequately ventilated suitable box on open deck.

11.3.2 Vented batteries connected to a charging device with a power output within the range 0,2 kW to 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, are to be installed in accordance with 11.3.1, or may be installed within a well ventilated machinery or similar space.

11.3.3 Vented batteries connected to a charging device with a power output of less than 0,2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, may be installed in an open position or in a battery box in any suitable space.

11.3.4 Where more than one charging device is installed for any battery or group of batteries in one location, the total power output is to be used to determine the installation requirements of 11.3.1, 11.3.2 or 11.3.3.

11.3.5 Valve-regulated sealed batteries may be located in compartments with standard marine or industrial electrical equipment provided that the ventilation requirements of 11.5.10 and the charging requirements of 11.6.4 and 11.6.5 are complied with. Equipment that may produce arcs, sparks or high temperatures in normal operation is not to be in close proximity to battery vent plugs or pressure relief valve outlets.

11.3.6 Where lead-acid and nickel-cadmium batteries are installed in the same compartment precautions are to be taken, such as the provision of screens, to prevent possible contamination of electrolytes.

11.3.7 Where batteries may be exposed to the risk of mechanical damage or falling objects they are to be suitably protected.

11.3.8 Batteries installed in crew and passenger cabins, together with their associated corridors, are to be of the hermetically sealed type.

11.3.9 A permanent notice prohibiting smoking and the use of naked lights or equipment, capable of creating a source of ignition, is to be prominently displayed adjacent to the entrances of all compartments containing batteries.

11.3.10 Only electrical equipment necessary for operational reasons and for the provision of lighting is to be installed in compartments provided in compliance with 11.3.1. Such electrical equipment is to be certified for group IIC gases and temperature Class T1 in accordance with IEC 60079: *Electrical apparatus for explosive gas atmospheres*, or an acceptable and relevant National Standard.

11.3.11 A permanent notice is to be prominently displayed adjacent to battery installations advising personnel that replacement batteries are to be of an equivalent performance type. For valve-regulated sealed batteries, the notice is to advise of the requirement for replacement batteries to be suitable with respect to products of electrolysis and evaporation being allowed to escape from cells to the atmosphere, *see also* 1.4.3.

11.4 Installation

11.4.1 Batteries are to be arranged such that each cell or crate of cells is accessible from the top and at least one side and it is to be ensured that they are suitably secured to move with the craft's motion. For high speed craft, the securing arrangements for batteries are to, as far as practicable, prevent excessive movement during the accelerations due to grounding or collision.

11.4.2 The materials used in the construction of a battery rack or stand are to be resistant to the battery electrolyte or suitably protected by paint or a coating.

11.4.3 Measures are to be taken to minimise the effect of any electrolyte spillage and leakage, for example the use of rubber capping around the top of the cells and the provision of a tray of electrolyte-resistant material below the cells, unless the deck is suitably protected with paint or a coating.

11.4.4 The interiors of all compartments for batteries, including crates, trays, boxes, shelves and other structural parts therein, are to be of an electrolyte-resistant material or suitably protected, for example with paint or a coating.

11.4.5 High speed craft are to be provided with an alarm to indicate that immediate action is required in the event of thermal runaway of any nickel cadmium battery.

11.5 Ventilation

11.5.1 Battery compartments and boxes are to be ventilated to avoid accumulation of dangerous concentrations of flammable gas. The ventilation openings are to be of a non-closeable type and a permanent notice is to be prominently displayed adjacent to them, stating:

THIS VENTILATOR OPENING IS NOT TO BE CLOSED OR BLOCKED AT ANY TIME – EXPLOSIVE GAS.

11.5.2 Ducted natural ventilation may be employed for battery installations connected to a charging device with a power output of 2 kW or less, provided the exhaust duct can be run directly from the top of the compartment or box to the open air above, with no part of the duct more than 45° from the vertical. A suitable opening is also to be provided below the level of the top of the batteries, so as to ensure a free ventilation air flow. The ventilation duct is to have an area not less than 50 cm^2 for every 1 m^3 of battery compartment or box volume.

11.5.3 Where natural ventilation is impracticable or insufficient, mechanical ventilation is to be provided, with the air inlet located near the floor and the exhaust at the top of the compartment.

11.5.4 Mechanical exhaust ventilation complying with 11.5.9 is to be provided for battery installations connected to a charging device with a total maximum power output of more than 2 kW and also, to minimise the possibility of oxygen enrichment, compartments and spaces containing batteries with boost charging facilities are to be provided with mechanical exhaust ventilation irrespective of the charging device power output.

11.5.5 The ventilation system for battery compartments and boxes, other than boxes located on open deck or in spaces to which 11.3.2, 11.3.3 and 11.3.5 refer, is to be separate from other ventilation systems. The exhaust ducting is to be led to a location in the open air, where any gases can be safely diluted, away from possible sources of ignition and openings into spaces where gases may accumulate.

11.5.6 Fan motors associated with exhaust ducts from battery compartments are to be placed external to the ducts and the compartments.

11.5.7 Ventilating fans for battery compartments are to be so constructed and be of material such as to minimise risk of sparking in the event of the impeller touching the casing. Non-metallic-impellers are to be of an anti-static material.

11.5.8 Battery boxes are to be provided with sufficient ventilation openings located so as to avoid accumulation of flammable gas whilst preventing the entrance of rain or spray.

11.5.9 The ventilation arrangements for all installations of vented type batteries are to be such that the quantity of air expelled is at least equal to:

$$Q = 110 I n$$

where

n = number of cells in series

I = maximum current delivered by the charging equipment during gas formation, but not less than 25 per cent of the maximum obtainable charging current in amperes

Q = quantity of air expelled in litres/hr.

11.5.10 The ventilation rate for compartments containing valve-regulated sealed batteries may be reduced to 25 per cent of that given in 11.5.9.

11.6 Charging facilities

11.6.1 Charging facilities are to be provided for all secondary batteries such that they may be completely charged from the completely discharged state in a reasonable time having regard to the service requirements.

11.6.2 Suitable means, including an ammeter and a voltmeter, are to be provided for controlling and monitoring charging of batteries, and to protect them against discharge into the charging circuits.

11.6.3 For floating circuits or any other conditions where the load is connected to the battery whilst it is on charge, the maximum battery voltage is not to exceed the safe value for any connected apparatus.

11.6.4 Where valve-regulated sealed batteries are installed, the charging facilities are to incorporate independent means such as overvoltage protection to prevent gas evolution in excess of the manufacturer's design quantity.

11.6.5 Boost charge facilities, where provided, are to be arranged such that they are automatically disconnected should the battery compartment ventilation system fail.

11.7 Recording of batteries for emergency and essential services

11.7.1 A schedule of batteries fitted for use for essential and emergency services is to be compiled and maintained.

11.7.2 Procedures are to be put in place and documented to ensure that, where batteries are replaced, they are of an equivalent performance type, *see also* 1.4.3.

11.7.3 When additions or alterations are proposed to the existing batteries for essential and emergency services, the schedule and replacement procedure documentation are to be updated to reflect the proposed installation and submitted in accordance with 1.4.2.

11.7.4 The schedule and replacement procedure documentation are to be made available to the LR Surveyor on request.

11.8 Cables

11.8.1 Where it is impracticable to provide electrical protective devices for certain cables supplied from batteries, e.g. within battery compartments and in engine starting circuits, unprotected cable runs are to be kept as short as possible and special precautions should be taken to minimise risk of faults, e.g., use of single core cables with additional sleeve over the insulation of each core, with shrouded terminals.

Section 12
Equipment – Heating, lighting and accessories

12.1 Heating and cooking equipment

12.1.1 The construction of heaters is to give a degree of protection according to IEC 60529: *Degrees of protection provided by enclosures (IP Code)*, or an acceptable and relevant National Standard, suitable for the intended location.

12.1.2 Heating elements are to be suitably guarded.

12.1.3 Heating and cooking equipment is to be installed such that adjacent bulkheads and decks are not subjected to excessive heating.

12.2 Lighting – General

12.2.1 Lampholders are to be constructed of flame retarding non-hygroscopic materials.

12.2.2 Lighting fittings are to be so arranged as to prevent temperature rises which overheat or damage surrounding materials. They must not impair the integrity of fire divisions.

12.3 Incandescent lighting

12.3.1 Tungsten filament lamps and lampholders are to be in accordance with Table 2.12.1.

12.3.2 Lampholders of type E40 are to be provided with a means of locking the lamp in the lampholder.

12.4 Fluorescent lighting

12.4.1 Fluorescent lamps and lampholders are to be in accordance with Table 2.12.1.

12.4.2 Fittings, reactors, capacitors and other auxiliaries are not to be mounted on surfaces which are subject to high temperatures. If mounted separately they are additionally to be enclosed in an earthed conductive casing.

12.4.3 Where capacitors of 0,5 microfarads and above are installed, means are to be provided to promptly discharge the capacitors on disconnection of the supply.

12.5 Discharge lighting

12.5.1 Discharge lamps operating in excess of 250 V are only acceptable as fixed fittings. Warning notices calling attention to the voltage are to be permanently displayed at points of access to the lamps and where otherwise necessary.

Table 2.12.1 Lamps and lampholders

Designation	Maximum lamp rating		Maximum lampholder current, A
	Voltage, V	Power, W	
Screw cap lamps			
E40	250	3000	16
E27	250	200	4
E14	250	15	2
E10	24	–	2
Bayonet cap lamps			
B22	250	200	4
B15d	250	15	2
B15s	55	15	2
Tubular fluorescent lamps			
G13	250	80	–
G5	250	13	–

12.6 Socket outlets and plugs

12.6.1 The temperature rise on the live parts of socket outlet and plugs is not to exceed 30°C. Socket outlets and plugs are to be so constructed that they cannot be readily short-circuited whether the plug is in or out, and so that a pin of the plug cannot be made to earth either pole of the socket outlet.

12.6.2 All socket outlets of current rating in excess of 16 A are to be provided with a switch, and be interlocked such that the plug cannot be inserted or withdrawn when the switch is in the ‘on’ position.

12.6.3 Where it is necessary to earth the non-current carrying parts of portable or transportable equipment, an effective means of earthing is to be provided at the socket outlet.

12.6.4 On weather decks, galleys, laundries, machinery spaces and all wet situations socket outlets and plugs are to be effectively shielded against rain and spray and are to be provided with means of maintaining this quality after removal of the plug.

12.7 Enclosures

12.7.1 Enclosures for the containing and mounting of electrical accessories are to be of metal, effectively protected against corrosion, or of flame-retardant insulating materials.

■ *Section 13* Electrical equipment for use in explosive atmospheres

13.1 General

13.1.1 Electrical equipment is not to be installed in areas where an explosive atmosphere may be present, except where necessary for operational and/or safety purposes, when the equipment is to be of a certified safe type as listed below and details of the equipment and installation are to be submitted for consideration. The construction and type testing is to be in accordance with IEC 60079: *Electrical Equipment for Explosive Gas Atmospheres* or an acceptable and relevant National Standard.

Intrinsically safe	–	Ex ‘i’
Increased safety	–	Ex ‘e’
Flameproof	–	Ex ‘d’
Pressurized enclosure	–	Ex ‘p’
Powder filled	–	Ex ‘q’
Encapsulated	–	Ex ‘m’

13.1.2 Where cables are installed in hazardous areas, precautions are to be taken against risks being introduced in the event of an electrical fault.

13.1.3 For craft with spaces for carrying vehicles with fuel in their tanks for their own propulsion, the following requirements are also applicable:

(a) electrical equipment fitted within a height of 45 cm above the vehicle deck, or any platform on which vehicles are carried, or within the exhaust ventilation trunking for the space, is to be of a safe type;

(b) electrical equipment situated elsewhere within the space is to have an enclosure of ingress protection rating of at least IP55, if not of a safe type. (*See* IEC 60529: *Classification of Degrees of Protection Provided by Enclosures*). Smoke and gas detector heads are exempt from this requirement.

■ *Section 14* Navigation and manoeuvring systems

14.1 Steering systems

14.1.1 The requirements of 14.1.2 to 14.1.7 are to be read in conjunction with those in Pt 14, Ch 1.

14.1.2 Two exclusive circuits, fed from the main source of electrical power and each having adequate capacity to supply all the motors which may be connected to it simultaneously are to be provided for each electric or electrohydraulic steering unit arrangement consisting of one or more electric motors. One of these circuits may pass through the emergency switchboard. For high speed craft, one of these circuits is to be fed either from the emergency source of electric power or from an independent power source located in such a position as to be unaffected by fire or flooding affecting the main source of power. (*See also* Pt 14, Ch 1,6).

14.1.3 The main and auxiliary steering unit motors are to be capable of being started from a position on the navigating bridge and also arranged to restart automatically when power is restored after a power failure.

14.1.4 The motor of an associated auxiliary electric or electrohydraulic power unit may be connected to one of the circuits supplying the main steering unit.

14.1.5 Only short circuit protection is to be provided for each main and auxiliary steering unit motor circuit.

14.1.6 In craft of less than 1600 gross tonnage, if an auxiliary steering unit is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering unit may be fed by one circuit from the main switchboard. Consideration would be given to other protective arrangements other than described in 14.1.5 for such a motor primarily intended for other services.

14.1.7 Each main and auxiliary steering unit electric control system which is to be operated from the navigating bridge is to be served with electric power by a separate circuit supplied from the associated steering gear power circuit, from a point within the steering unit compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering unit power circuit is connected. Each separate circuit is to be provided with short circuit protection only.

14.2 Thruster systems for manoeuvring

14.2.1 Where a tunnel or athwartship thruster is fitted solely for the purpose of manoeuvring, and is electrically driven, its starting and operation is not to cause the loss of any essential services.

14.2.2 In order to ensure that the thruster system is not tripped inadvertently whilst manoeuvring the craft, overload protection in the form of an alarm is to be provided for the electric motor and any associated supply converters, in lieu of tripping.

14.2.3 The thruster electric motor is not to be disconnected as part of a load management switching operation.

14.3 Navigation lights

14.3.1 Navigation lights are to be connected separately to a distribution board reserved for this purpose only and accessible to the officer of the watch. This distribution board is to be connected directly or through transformers to the emergency source of electrical power in compliance with, for passenger craft, 3.2.7(b)(i) and (ii) and 3.2.9(a) or, for cargo craft, 3.3.8(b)(i) and (ii) and 3.3.8(a).

14.3.2 Each navigation light is to be controlled and protected in each insulated pole by a switch and fuse or circuit-breaker mounted on the distribution board.

14.3.3 Each navigation light is to be provided with an automatic indicator giving audible and/or visual indication of failure of the light. If an audible device alone is fitted, it is to be connected to an independent source of supply, e.g. a battery, with means provided to test this supply. If a visual signal is used connected in series with the navigation light, means are to be provided to prevent extinction of the navigation light due to failure of the signal. The requirements of this paragraph do not apply to pilot boats, fishing boats and similar small vessels.

14.3.4 Provision is to be made on the navigating bridge for the navigation lights to be transferred to an alternative circuit fed from the main source of electrical power.

14.3.5 Any statutory requirements of the country of registration are to be complied with and may be accepted as an alternative to the above.

14.4 Navigational aids

14.4.1 Navigational aids as required by statutory regulations are to be fed from the emergency source of electrical power. (*See also* 3.2.7(d)(i) and 3.3.7(d)(i))

14.5 Stabilization

14.5.1 Where the stabilization of a craft is essentially dependent upon a single device which in turn is dependent upon a continuous supply of electrical power, the supply arrangements are to comply with 5.2.3.

14.5.2 Where such systems are not dependent upon the continuous availability of electrical power, but one or more alternative systems not dependent upon the electrical supply are installed, a single circuit may be provided, with the protection and alarms required by 5.2.3.

■ *Section 15* Electric propulsion

15.1 General

15.1.1 Where electric propulsion is proposed, details are to be submitted and the arrangements will be subject to special consideration.

■ *Section 16* Fire safety systems

16.1 Fire detection and alarm systems

16.1.1 Fire detection and alarm systems are to be provided with an emergency source of electrical power required by 3.2, 3.3, 3.4 or 19.10 and are also to be connected to the main source of electrical power. Separate feeders, reserved solely for this purpose, with automatic changeover facilities located in, or adjacent to, the main fire detection control panel are to be provided. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.13 and 1.14.

16.1.2 For machinery spaces the requirements of Ch 1,2.8 are applicable.

16.1.3 The fire detection system within the accommodation spaces is in addition to the requirements of Chapter 1, as applicable, to comply with 16.1.4 to 16.1.15.

16.1.4 The fire control panel is to be located on the navigating bridge or in a central fire control station and may form part of that panel specified in Ch 1,2.8.2. In passenger craft carrying more than 36 passengers, the fire control panel is to be located in the continuously manned central control station.

16.1.5 Detectors and manually operated call points are to be grouped into sections. The activation of any detector or manually operated call point is to initiate a visual and audible fire signal at the control panel and indicating units. If the signals have not received attention within two minutes an audible alarm is to be automatically sounded throughout the crew accommodation and service spaces, control stations and machinery spaces of Category A. This alarm sounder system need not be an integral part of the detection system.

16.1.6 Indicating units are to denote, as a minimum, the section in which a detector or manually operated call point has operated. At least one unit is to be so located that it is easily accessible to responsible members of the crew. One indicating unit is to be located on the navigating bridge if the control panel is located in the central control station.

16.1.7 Clear information is to be displayed on or adjacent to each indicating unit about the spaces covered and the location of the section.

16.1.8 Where the fire detection system does not include means of remotely identifying each detector individually no section covering more than one deck within accommodation, service spaces and control stations is normally to be permitted except a section which covers an enclosed stairway. The number of enclosed spaces in each section are to be limited to the minimum considered necessary in order to avoid delay in identifying the source of fire. In no case are more than fifty spaces permitted in any section.

16.1.9 In passenger craft, where the fire detection system does not include means of remotely identifying each detector individually a section of detectors is neither to serve spaces on both sides of the craft nor on more than one deck except when permitted by 16.1.4.

16.1.10 A section of fire detectors which covers a control station, a service space or an accommodation space is not to include a machinery space of Category A.

16.1.11 The fire detection system is not to be used for any other purpose, except that closing of fire doors and similar functions may be permitted at the control panel.

16.1.12 A loop circuit of an addressable fire detection system, capable of remotely identifying from either end of the loop, individually each detector served by the circuit, may serve spaces on both sides of the craft and on several decks, but is not to be situated in more than one main vertical or horizontal fire zone, nor is a loop circuit which covers a control station or an accommodation space to include a machinery space of Category A.

16.1.13 A loop circuit of an addressable fire detection system may comprise one or more sections of detectors. Where the loop comprises more than one section, the sections are to be separated by devices which will ensure that if a short-circuit occurs anywhere in the loop, only the affected section of detectors will be isolated from the control panel. No section of detectors is in general to include more than 50 detectors.

16.1.14 A section of detectors of an addressable fire detection system is neither to serve spaces on both sides of the craft nor on more than one deck, except that:

(a) a section of detectors may serve spaces on more than one deck if those spaces are located in either the fore or aft end of the craft, or they constitute common spaces occupying several decks, i.e. public spaces, enclosed stairways, etc.

(b) in craft of less than 20 m in breadth, a section of detectors may serve spaces on both sides of the craft.

16.1.15 The wiring for each section of detectors in an addressable fire detector system is to be separated as widely as practicable from that of all other sections on the same loop. When this is not practical, such as in large public spaces, the part of the loop which by necessity passes through the space for a second time is to be installed at the maximum possible distance from other parts of the loop.

16.2 Automatic sprinkler system

16.2.1 Any electrically driven power pump, provided solely for the purpose of continuing automatically the discharge of water from the sprinklers, is to be brought into action automatically by the pressure drop in the system before the standing fresh water charge in the pressure tank is completely exhausted.

16.2.2 For passenger craft, electrically driven sea-water pumps for automatic sprinkler systems are to be served by not less than two circuits reserved solely for this purpose, one fed from the main source of electrical power and one from the emergency source of electrical power. Such feeders are to be connected to an automatic change-over switch situated near the sprinkler pump and the switch is to be normally closed to the feeder from the main source of electrical power. No other switches are permitted in the feeders. The switches on the main and emergency switchboards are to be clearly labelled and normally kept closed.

16.2.3 The automatic alarm and detection system is to be fed by exclusive feeders from two sources of electrical power, one of which is to be an emergency source, with automatic change-over facilities located in, or adjacent to, the main alarm and detection panel.

16.2.4 Feeders for the sea-water pump and the automatic alarm and detection system are to be arranged so as to avoid galleys, machinery spaces and other enclosed spaces of high fire risk, except in so far as it is necessary to reach the appropriate switch boards. The cables are to be of a fire resistant type where they pass through such high risk areas.

16.3 Fixed water-based local application fire-fighting systems

16.3.1 Where fixed water-based local application fire-fighting system pressure sources are reliant on external power they need only be supplied by the main source of electrical power. However, where the system forms a section of the main fixed fire-extinguishing system the power supply arrangements are to be equivalent to those required by 16.2.2.

16.3.2 The fire detection, control and alarm systems are to be provided with an emergency source of electrical power required by 3.2, 3.3 or 3.4 and are also to be connected to the main source of electrical power. Separate feeders, reserved solely for this purpose, with automatic changeover facilities located in, or adjacent to, the main control panel are to be provided.

16.3.3 Failure of any power supply is to operate an audible and visual alarm. *See also* 1.13 and 1.14.

16.3.4 Means to activate a system are to be located at easily accessible positions inside and outside the protected space. Arrangements inside the space are to be situated such that they will not be cut off by a fire in the protected areas and are suitable for activation in the event of escape. Proposals to install local activation means outside protected spaces are to be submitted for consideration.

16.3.5 For the electrical safety of electrical and electronic equipment in areas protected by fixed water-based local application, fire-fighting systems and adjacent areas where water may extend, the requirements of 16.3.6 to 16.3.8 apply.

16.3.6 Unless essential for safety or operational purposes, electrical and electronic equipment is not to be located within protected areas or adjacent areas. The pump, its electrical motor and the sea valve if any, may be in a protected space provided that they are outside areas where water or spray may extend.

16.3.7 Electrical and electronic equipment located within protected areas and those within adjacent areas exposed to direct spray are to have a degree of protection not less than IP44.

16.3.8 Electrical and electronic equipment within adjacent areas not exposed to direct spray may have a lower degree of protection than IP44 provided evidence of suitability for use in these areas is submitted, including details of the design and equipment layout and arrangements to prevent or restrict the ingress of water mist/spray. Cooling airflow for equipment is to be assured.

16.4 Fire pumps

16.4.1 When the emergency fire pump is electrically driven, the power is to be supplied by a source other than that supplying the main fire pumps. This source is to be located outside the machinery spaces containing the main fire pumps and their source of power and drive units.

16.4.2 The cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source of power and drive units. The cables are to be of a fire resistant type where they pass through other high fire risk areas.

16.5 Refrigerated liquid carbon dioxide systems

16.5.1 Where there are electrically driven refrigeration units for carbon dioxide fire-extinguishing systems, one unit is to be supplied by the main source of electrical power and the other unit from the emergency source of electrical power.

16.5.2 Each electrically driven carbon dioxide refrigerating unit is to be arranged for automatic operation in the event of loss of the alternative unit.

16.6 Fire safety stops

16.6.1 In order to limit the fire growth potential in every space of the craft, means for controlling the air supply to the spaces and flammable liquids within the spaces are to be provided.

16.6.2 To control air supply, a means of stopping all forced and induced draught fans, and all ventilation fans serving accommodation spaces, service spaces, control stations and machinery spaces from an easily accessible position outside of the space being served is to be provided. The position is not to be readily cut off in the event of a fire in the spaces served by the fans.

16.6.3 In passenger craft carrying more than 36 passengers, a second means of stopping ventilation fans serving accommodation spaces, service spaces and control stations is to be provided at a position as far apart from the position required by 16.6.2 as is practicable. At both positions, the controls are to be grouped so that all fans can be stopped from either of the two positions.

16.6.4 A second means of stopping ventilation fans serving machinery spaces is to be provided at a position as far apart from the position required by 16.6.2 as is practicable. At both positions the controls are to be grouped so that all fans are operable from either of the two positions. The means for stopping machinery space ventilation fans are to be entirely separate from the means for stopping fans serving all other spaces.

16.6.5 In passenger craft, the means of stopping machinery ventilation fans required by 16.6.2 is to be located at the central control station which is to have safe access from the open deck. The central control station is to be provided with ventilation fan OFF status indications, together with a means for restarting the ventilation fans.

16.6.6 To control flammable liquids, a means of stopping all fuel oil, lubricating oil, hydraulic oil, cargo oil and thermal oil pumps and oil purifiers from outside the spaces being served is to be provided. The position is not to be cut off in the event of a fire.

16.6.7 Means of cutting off power to the galley, in the event of a fire, are to be provided outside the galley exits, at positions which will not readily be rendered inaccessible by such a fire.

16.6.8 Following activation of any fire safety stops, a manual reset is to be provided in order to restart the associated equipment.

16.6.9 Fire safety stop systems are to be designed on the fail-safe principle or alternatively the power supplies to, and the circuits of, the fire safety stop systems are to be continuously monitored and an alarm initiated in the event of a fault. Cables are to be of a fire-resistant type, *see* 10.5.3. *See also* 5.2.1.

16.6.10 High speed craft bridge areas are to be provided with suitable emergency means to:

(a) close ventilation openings and stop ventilating machinery supplying spaces covered by fixed fire-extinguishing systems;
(b) shut off fuel supplies to machinery in main and auxiliary machinery spaces; and
(c) stop main engine(s) and auxiliary machinery.

NOTE
These emergency means are to be sited in conjunction with required fixed fire extinguishing system activation means.

16.6.11 Additionally, Passenger (B) high speed craft are to be provided with the means required by 16.6.10 at one or more alternative stations separate from the bridge area. *See also* Ch 1,2.6.7.

16.7 Fire doors

16.7.1 The electrical power required for the control, indication and alarm circuits of fire doors is to be provided by an emergency source of electrical power as required by 3.2. In passenger craft carrying more than 36 passengers an alternative supply fed from the main source of electrical power, with automatic change-over facilities, is to be provided at the central control station. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.13 and 1.14.

16.7.2 The control and indication systems for the fire doors are to be designed on the fail-safe principle with the release system having a manual reset.

16.8 Fire dampers

16.8.1 The electrical power required for the control and indication circuits of fire dampers is to be supplied from the emergency source of electrical power.

16.8.2 The control and indication systems for the fire dampers are to be designed on the fail-safe principle with the release system having a manual reset.

16.9 Fire-extinguishing media release alarms

16.9.1 Where it is required that alarms be provided to warn of the release of a fire extinguishing medium, and these are electrically operated, they are to be provided with an emergency source of electrical power, as required by 3.2, 3.3 or 3.4 and also connected to the main source of electrical power, with automatic changeover facilities located in, or adjacent to, the fire-extinguishing media release panel, *see also* 1.13. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.13 and 1.14.

■ *Section 17*
Crew and passenger emergency safety systems

17.1 Emergency lighting

17.1.1 For the purpose of this Section emergency lighting, transitional emergency lighting and supplementary emergency lighting are hereafter referred to under the generic name 'emergency lighting'.

17.1.2 Emergency lighting provided in compliance with Section 3 is to be arranged so that a fire or other casualty in the spaces containing the emergency source of electrical power, associated transforming equipment and the emergency lighting switchboard does not render the main lighting system inoperative.

17.1.3 The level of illumination provided by the emergency lighting is to be adequate to permit safe evacuation in an emergency, having regard to the possible presence of smoke, *see* 17.4.

17.1.4 The exit(s) from every main compartment occupied by passengers or crew is to be continuously illuminated by an emergency lighting fitting.

17.1.5 Switches are not to be installed in the final sub-circuits to emergency light fittings unless the light fittings are serving normally unmanned spaces, i.e. storage-rooms, cold rooms, etc., or they are normally required to be extinguished for operational reasons, i.e. for night visibility from the navigating bridge. Where switches are fitted they are to be accessible only to craft crew with provision made to ensure that the emergency lighting is energised when such spaces are manned and/or during emergency conditions.

17.1.6 Where emergency lighting fittings are connected to dimmers, provision is to be made, upon the loss of the main lighting, to automatically restore them to their normal level of illumination.

17.1.7 Fittings are to be specially marked to indicate that they form part of the emergency lighting system.

17.2 General emergency alarm system

17.2.1 An electrically operated bell or klaxon or other equivalent warning system installed in addition to the craft's whistle or siren, for sounding the general emergency alarm signal, is to comply with the *International Life-saving Appliances (LSA) Code* and with the requirements of this Section, *see also* 1.13 and 1.14.

17.2.2 The general emergency alarm system is to be provided with an emergency source of electrical power as required by 3.2, 3.3, 3.4 or 19.10 and also connected to the main source of electrical power with automatic changeover facilities located in, or adjacent to, the main alarm signal distribution panel. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.13.

17.2.3 The general emergency alarm distribution system is to be so arranged that a fire or casualty in any one main vertical zone, as defined by SOLAS Reg. II-2/A, Reg. 3.9, other than the zone in which the public address control station is located, will not interfere with the distribution in any other such zone.

17.2.4 There are to be segregated cable routes to public rooms, alleyways, stairways, and control stations, so arranged that any single electrical fault, localised fire or casualty will not cause the loss of the facility to sound the general emergency alarm in any public rooms, alleyways, stairways, and control stations, be it at a reduced capacity.

17.2.5 Where the special alarm fitted to summon the crew, operated from the navigation bridge, or fire control station, forms part of the craft's general alarm system, it is to be capable of being sounded independently of the alarm to the passenger spaces.

17.2.6 The sound pressure levels are to be measured during a practical test and documented, *see* 20.2.

17.3 Public address system

17.3.1 Public address systems are to comply with the *International Life-saving Appliances (LSA) Code* and the requirements of this Section.

17.3.2 The public address system is to be provided with an emergency source of electrical power as required by 3.2, 3.3, 3.4 or 19.10 and also connected to the main source of electrical power with automatic changeover facilities located adjacent to the public address system. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.13 and 1.14.

17.3.3 The public address system is to have multiple amplifiers having their power supplies so arranged that a single fault will not cause the loss of the facility to broadcast emergency announcements in public rooms, alleyways, stairways and control stations, albeit at a reduced capacity.

17.3.4 The public address distribution system is to be so arranged that a fire or casualty in any one main vertical zone, as defined by SOLAS Reg. II-2/A, Reg.3.9, other than the zone in which the public address control station is located, will not interfere with the distribution in any other such zone.

17.3.5 There are to be segregated cable routes to public rooms, alleyways, stairways, and control stations so arranged that any single electrical fault, fire or casualty will not cause the loss of the facility to broadcast emergency announcements in any public rooms, alleyways, stairways, and control stations, albeit at a reduced capacity.

17.3.6 Amplifiers are to be continuously rated for the maximum power that they are required to deliver into the system for audio and, where alarms are to be sounded through the public address system, for tone signals.

17.3.7 Loudspeakers are to be continuously rated for their proportionate share of amplifier output and protected against short-circuits.

17.3.8 Amplifiers and loudspeakers are to be selected and arranged to prevent feedback and other interference. There are also to be means to automatically override any volume controls, so as to ensure the specified sound pressure levels are met.

17.3.9 Where the public address system is used for sounding the general emergency alarm and the fire-alarm, the following requirements are to be met in addition to those of 17.2:

(a) The emergency system is given automatic priority over any other system input.

(b) More than one device is provided for generating the sound signals for the emergency alarms.

17.3.10 Where more than one alarm is to be sounded through the public address system, they are to have recognisably different characteristics and additionally be arranged, so that any single electrical failure which prevents the sounding of any one alarm will not affect the sounding of the remaining alarms.

17.3.11 The sound pressure levels are to be measured during a practical test using speech and, where applicable, tone signals, and documented, *see* 20.2.

17.4 Escape route or low location lighting (LLL)

17.4.1 Where required escape route or low location lighting (LLL) is satisfied by electric illumination, the LLL system is to comply with the requirements of this sub-Section.

17.4.2 The LLL system is to be provided with an emergency source of electrical power and also be connected to the main source of electrical power, with automatic changeover facilities located adjacent to the control panel, *see also* 1.14.

17.4.3 The power supply arrangements to the LLL are to be arranged so that a single fault or a fire in any one fire zone or deck does not result in loss of the lighting in any other zone or deck. This requirement may be satisfied by the power supply circuit configuration, use of fire-resistant cables complying with 10.5.3, and/or the provision of suitably located power supply units having integral batteries adequately rated to supply the connected LLL for a minimum period of 60 minutes, *see* 11.3.7.

17.4.4 The performance and installation of lights and lighting assemblies are to comply with ISO standard 15370: *Ships and marine technology – Low location lighting on passenger ships*.

■ *Section 18*
Craft safety systems

18.1 Watertight doors

18.1.1 The electrical power required for power-operated sliding watertight doors is to be separate from any other power circuit and supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the waterline in the final condition of damage or above the bulkhead deck as applicable. The associated control, indication and alarm circuits are to be supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the waterline in the final condition of damage or above the bulkhead deck as applicable and for passenger craft be capable of being automatically supplied by the transitional source of emergency electrical power required by 3.2.6 or, where applicable, 3.3.5 in the event of failure of either the main or emergency source of electrical power.

18.1.2 For passenger craft, where the sources for opening and closing the watertight doors have electric motors, unless an independent temporary source of stored energy is provided, the electric motors are to be capable of being automatically supplied from the transitional source of emergency electrical power.

18.1.3 A single failure in the power operating or control system of power-operated sliding watertight doors is not to result in a closed door opening or prevent the hand operation of any door.

18.1.4 Availability of the power supply is to be continuously monitored at a point in the electrical circuit adjacent to the door operating equipment. Loss of any such power supply is to activate an audible and visual alarm at the central operating console at the navigating bridge.

18.1.5 Electrical power, control, indication and alarm circuits are to be protected against fault in such a way that a failure in one door circuit will not cause a failure in any other door circuit. Short circuits or other faults in the alarm or indicator circuits of a door are not to result in a loss of power operation of the door. Arrangements are to be such that leakage of water into the electrical equipment located below the bulkhead deck will not cause the door to open.

18.1.6 The enclosures of electrical components necessarily situated below the waterline in the final condition of damage or below the bulkhead deck as applicable are to provide suitable protection against the ingress of water with ratings as defined in IEC 60529 or an acceptable and relevant national standard, as follows:

(a) Electrical motors, associated circuits and control components, protected to IPX7 standard.
(b) Door position indicators and associated circuit components protected to IPX8 standard, where the water pressure testing of the enclosures is to be based on the pressure that may occur at the location of the component during flooding for a period of 36 hours.
(c) Door movement warning signals, protected to IPX6 standard.

18.1.7 Watertight door electrical controls including their electric cables are to be kept as close as is practicable to the bulkhead in which the doors are fitted and so arranged that the likelihood of them being involved in any damage which the craft may sustain is minimised.

18.1.8 An audible alarm, distinct from any other alarm in the area, is to sound whenever the door is closed remotely by power and sound for at least five seconds but no more than ten seconds before the door begins to move and is to continue sounding until the door is completely closed. The audible alarm is to be supplemented by an intermittent visual signal at the door in passenger areas and areas where the noise level exceeds 85 dB(A).

18.1.9 A central operating console is to be fitted on the navigating bridge and is to be provided with a 'master-mode' switch having:

(a) a 'local control' mode for normal use which is to allow any door to be locally opened and locally closed after use without automatic closure, and;
(b) a 'doors closed' mode for emergency use which is to allow any door that is opened to be automatically closed whilst still permitting any doors to be locally opened but with automatic reclosure upon release of the local control mechanism.

18.1.10 The 'master mode' switch is to be arranged to be normally in the 'local control' mode position; be clearly marked as to its emergency function and be Type Approved in accordance with LR's Procedure for Type Approved Products.

18.1.11 The central operating console at the navigating bridge is to be provided with a diagram showing the location of each door, with visual indicators to show whether each door is open or closed. A red light is to indicate a door is fully open and a green light, a door fully closed. When the door is closed remotely a red light is to indicate the intermediate position by flashing. The indicating circuit is to be independent of the control circuit for each door.

18.1.12 The arrangements are to be such that it is not possible to remotely open any door from the central operating console.

18.2 Shell doors, loading doors and other closing appliances

18.2.1 Where it is required that indicators be provided for shell doors, loading doors and other closing appliances, which are intended to ensure the watertight integrity of the craft's structure in which they are located, the indicator system is to be designed on the fail-safe principle. The system is to indicate if any of the doors or closing appliances are open or are not fully closed or secured.

18.2.2 Where such doors and appliances are to be operated at sea, the requirements of 18.1 are to be complied with as far as is practicable.

18.2.3 The electrical power supply for the indicator system is to be independent of any electrical power supply for operating and securing the doors.

■ *Section 19*
Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt

19.1 General requirements

19.1.1 The requirements of this Section are applicable to electrical installations where the voltage of supply does not exceed 440 V a.c. or d.c.

19.1.2 The electrical installations for propulsion and auxiliary service where the voltage of supply exceeds 440 volts are to be constructed and installed in accordance with Sections 1 to 18.

19.1.3 Cargo craft of 300 tons gross tonnage and above are also to comply with 3.6.

19.1.4 Alternative arrangements will be given special consideration.

19.2 Plans

19.2.1 At least three copies of the plans and particulars in 19.2.2 to 19.2.6 are to be submitted for consideration. Single copies only are required of plans in 19.2.7.

19.2.2 Single line diagram of main power and lighting systems which is to include:
(a) rating of machines; transformers; batteries and semi-conductor converters;
(b) all feeders connected to the main switchboard;
(c) section boards and distribution boards;
(d) insulation type, size and current loadings of cables;
(e) make, type and rating of circuit breakers and fuses.

19.2.3 Simplified diagrams of generator circuits and feeder circuits showing:
(a) protective devices;
(b) instrumentation and control devices;
(c) preference tripping;
(d) earth fault indication/protection.

19.2.4 Calculations of short circuit currents at main switchboard and distribution boards, details of circuit breaker and fuse operating times and discrimination curves.

19.2.5 For battery installation, arrangement plans and calculations are to show compliance with 19.12.

19.2.6 Details of electrically operated personnel safety systems which are to include single line diagrams and a general arrangement plan of the vessel showing location and cable routes of:
(a) fire detection, alarm and extinction systems;
(b) internal communication and alarm systems.

19.2.7 Schedule of normal operating loads on the system.

19.3 Survey

19.3.1 The installation is to be inspected and tested by the Surveyors, in accordance with the requirements of Section 20, as appropriate, and is to be to their satisfaction.

19.4 Addition or alterations

19.4.1 No addition, temporary or permanent is to be made to an approved installation until it has been ascertained that the current carrying capacity and the condition of the existing equipment, including cables and switchgear, are adequate for the increased load.

19.4.2 Plans are to be submitted for consideration, and the alterations or additions are to be carried out under the survey and to the satisfaction of the Surveyors.

19.5 Location and construction of equipment

19.5.1 Electrical equipment is to be accessibly placed, clear of flammable material in well ventilated, adequately lighted spaces, in which flammable gases cannot accumulate and where it is not exposed to risk of mechanical damage or damage from water, steam or oil. Where necessarily exposed to such risks, the equipment is to be suitably constructed or enclosed. Equipment is to be accessible for maintenance.

19.5.2 Insulating materials and insulated windings are to be flame retardant, and resistant to tracking, moisture, sea air and oil vapour unless special precautions are taken to protect them.

19.5.3 Securing arrangements used in connection with current carrying parts are to be effectively locked.

19.5.4 The operation of all electrical equipment is to be satisfactory under such conditions of vibrations, movements and shock as may arise in normal practice.

19.5.5 The design and installation of electrical equipment is to be such that the risk of fire due to its failure is minimised. It is, as a minimum, to comply with a National or International Standard revised where necessary for ambient conditions. Equipment is to be tested at the manufacturer's works and a certificate of tests issued by the manufacturer.

19.6 Systems of distribution

19.6.1 The following systems of generation and distribution are acceptable:
(a) two wire insulated;
(b) two wire with one pole earthed;
(c) three phase three wire insulated neutral;
(d) three phase, four wire with neutral earthed but without hull return.

19.6.2 A device(s) is to be installed for every insulated distribution system, whether primary or secondary, for power, heating and lighting circuits to continuously monitor the insulation level to earth.

19.7 Earthing

19.7.1 Except where exempted by 19.7.2 all non-current carrying exposed metal parts of electrical equipment and cables are to be earthed.

19.7.2 The following parts may be exempted from the requirements of 19.7.1:
(a) lamp-caps, where suitably shrouded;
(b) shades, reflectors and guards supported in lampholders or light fittings constructed of, or shrouded in, non-conducting material;
(c) metal parts on, or screws in or through, non-conducting materials, which are separated by such material from current-carrying parts and from earthed non-current carrying parts in such a way that in normal use they cannot become live or come into contact with earthed parts;

(d) apparatus which is constructed in accordance with the principle of double insulation;
(e) bearing housings which are insulated in order to prevent circulation of current in the bearings;
(f) clips for fluorescent lamps;
(g) cable clips and short lengths of pipes for cable protection;
(h) apparatus supplied at a voltage not exceeding 55V direct current or 55V root mean square, between conductors, or between any conductor and earth in a circuit isolated from the supply. Autotransformers are not to be used for the purpose of achieving the alternating current voltage;
(j) apparatus or parts of apparatus which although not shrouded in insulating material is nevertheless otherwise so guarded that it cannot be touched and cannot come in contact with exposed metal.

19.7.3 With wood and other non-metallic hull constructions earthing connections are to be made to the generator frame, engine bedplate and earthing plate. Earthing connections are not to be made to hull sheathing, skin fittings or plumbing.

19.8 Protection

19.8.1 Installations are to be protected against overcurrents including short circuits. The tripping/fault clearance times of protective devices are to provide complete and co-ordinated protection to ensure:
(a) availability of services not affected by the faulty circuit;
(b) elimination of the fault to reduce damage to the system and hazard of fire.

19.8.2 Short circuit protection and a means of complete isolation is to be provided for each source of power.

19.8.3 Protection for battery circuits is to be provided at a position external and adjacent to the battery compartments; batteries used solely for engine starting may be provided with only a means of isolation.

19.8.4 Short circuit and overload protection together with a means of isolation is to be provided in each non-earthed outgoing circuit of the main switchboard and each distribution board.

19.8.5 Each final sub-circuit is to be provided with short circuit protection and a means of isolation in each non-earthed line.

19.8.6 Lighting circuits are to be supplied by circuits separate from those for power.

19.8.7 Control circuits for engine monitoring and other services are to be provided with short circuit protection.

19.8.8 Protective devices are not to be fitted in any earthed line of a distribution system.

19.8.9 Circuit breakers and fuses are to have a certified fault rating adequate for the installation and are to comply with a National or International Standard.

19.8.10 In the absence of precise data the calculation methods given in 6.2.4 are to be used for evaluation of short circuit currents.

19.8.11 Generators for a.c. systems are to be provided, as a minimum, with the protective gear required by 6.8.2 and 6.8.3 and additionally provided with the instrumentation required by 7.11.

19.9 Quality of power supplies

19.9.1 Unless specified otherwise electrical equipment, other than that supplied by battery systems, is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals:
(a) Voltage:
- Permanent variations +6%, –10%
- Transient recovery +20%, –15%
- Recovery time 1,5 seconds.

(b) Frequency:
- Permanent variations ±5% transient
- Variations ±10%
- Recovery time five seconds.

19.9.2 Generator voltage regulators and engine governors are to be such as to ensure that the above supply variations are not exceeded.

19.10 Sources of electrical power

19.10.1 Under sea-going conditions where electrical power is required for services for the propulsion, navigation and safety of the craft and crew, it is to be provided by either a generator(s) having a rating sufficient to ensure the operation of these services or by an engine-driven charging system in conjunction with a battery(ies).

19.10.2 Under emergency conditions where electrical power is required for lighting to enable persons to evacuate the craft, for navigational lights, fire detection and alarm systems and internal communication and alarm systems, it is to be provided by alternative source(s) of electrical power located separately from the source(s) of power in 19.10.1 and suitably located for use in an emergency. This source(s) of electrical power is to be adequate to permit evacuation and to supply the navigation lights, fire detection and alarm systems and internal communication and alarm systems, for a period of 5 hours duration.

19.10.3 Where electrical power is required for services for the propulsion, navigation and safety of the yacht or craft and for the safety of the crew it is to be provided by:
(a) for **non-passenger type yachts of scantling length between 24 m and 50 m**, at least two generators having ratings sufficient to ensure the operation of these services when any one generator is out of action; or
(b) for **non-passenger type service craft for Service Groups 1 to 3**, a generator(s) having a rating sufficient to ensure the operation of these services without being overloaded.

19.10.4 Additionally, for **non-passenger type yachts of scantling length between 24 m and 50 m**:

(a) generators fitted to satisfy the requirements of 19.10.3(a) may be driven by the main engine provided the requirements of 19.9.1 are satisfied for all main engine speed and load conditions and that there is at least one of the remaining generators driven by a prime mover independent of the main engine; and

(b) any batteries provided for the duty, referred to in 19.10.2, are to be rated for at least 5 hours duration.

19.10.5 Additionally, for **non-passenger type service craft for Service Groups 1 to 3**, in a single generator installation, or where in a multiple generator installation with one generator out of action the remaining generator(s) is not capable of supplying the circuits serving any safety, essential lighting and communication equipment, an alternative source of electrical power of 5 hours duration is to be provided for these services.

19.11 Cables

19.11.1 Cables and cable installations are to be in accordance with the requirements of Section 10.

19.12 Batteries

19.12.1 Batteries and battery installations are to be in accordance with the requirements of Section 11.

19.13 Lightning conductors

19.13.1 Lightning conductors complying with IEC 60092-401 are to be fitted to each mast of all wood, composite and steel craft having wooden masts or topmasts. They need not be fitted to steel craft having steel masts.

19.14 Fire detection and alarm systems

19.14.1 Where a fire detection and alarm system is fitted, it is to be in accordance with the requirements of 16.1.

19.15 Internal communication and alarm systems

19.15.1 Where internal communication and alarm systems are provided for use in an emergency, they are to comply with the requirements of 17.2 and 17.3 as appropriate.

■ *Section 20* Testing and trials

20.1 Testing

20.1.1 Tests in accordance with 20.1.2 to 20.1.4 are to be satisfactorily carried out on all electrical equipment, complete or in sections, at the manufacturer's premises and a test report issued by the manufacturer.

20.1.2 A high voltage at any frequency between 25 and 100 Hz is to be applied between:

(a) all current carrying parts connected together and earth;

(b) all current carrying parts of opposite polarity or phase.

For rotating machines the value of test voltage is to be 1000 V plus 2 x rated voltage with a minimum of 2000 V, and for other electrical equipment, it is to be in accordance with Table 2.20.1. Items of equipment included in the assembly for which a test voltage lower than the above is specified may be disconnected during the test and tested separately at the appropriate lower test voltage. The test is to be commenced at a voltage of about one-third the test voltage and is to be increased to full value as rapidly as is consistent with its value being indicated by the measuring instrument. The full test voltage is then to be maintained for one minute, and then reduced to one-third full value before switching off. The assembly is considered to have passed the test if no disruptive discharge occurs.

Table 2.20.1 Test voltage

Rated voltage, U_n U_n V	Test voltage a.c. (r.m.s.), V
$U_n \le 60$	500
$60 < U_n \le 1000$	$2 \times U_n + 1000$
$1000 < U_n \le 2500$	6500
$2500 < U_n \le 3500$	10000
$3500 < U_n \le 7200$	20000
$7200 < U_n \le 12000$	28000
$12000 < U_n \le 15000$	38000

20.1.3 When it is desired to make additional high voltage tests on equipment which has already passed its tests, the voltage of such additional tests is to be 80 per cent of the test voltage the equipment has already passed.

20.1.4 Immediately after the high voltage test, the insulation resistance is to be measured using a direct current insulation tester, between:

(a) all current carrying parts connected together and earth;

(b) all current carrying parts of different polarity or phase.

The minimum values of test voltage and insulation resistance are given in Table 2.20.2.

20.1.5 Tests in accordance with the standard with which the equipment complies may be accepted as an alternative to the above.

20.2 Trials

20.2.1 Before a new installation, or any alteration or addition to an existing installation, is put into service the applicable trials in 20.2.2 to 20.2.7 are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturer's works.

Table 2.20.2 Test voltage and minimum insulation

Rated voltage U_n V	Minimum voltage of the tests, V	Minimum insulation resistance, MΩ
$U_n \leq 250$	$2 \times U_n$	1
$250 < U_n \leq 1000$	500	1
$1000 < U_n \leq 7200$	1000	$\frac{U_n}{1000} + 1$
$7200 < U_n \leq 15000$	5000	$\frac{U_n}{1000} + 1$

20.2.2 The insulation resistance is to be measured of all circuits and electrical equipment, using a direct current insulation tester, between:

(a) all current carrying parts connected together and earth; and, so far as is reasonably practicable,

(b) all current carrying parts of different polarity or phase;

The minimum values of test voltage and insulation resistance are given in Table 2.20.2. The installation may be subdivided and appliances may be disconnected if initial tests produce results less than these figures.

20.2.3 Tests are to be made to verify the effectiveness of:

(a) earth continuity conductor;

(b) the earthing of non-current carrying exposed metal parts of electrical equipment and cables not exempted by 1.11.2 or 19.7.2;

(c) bonding for the control of static electricity.

20.2.4 It is to be demonstrated that the Rules have been complied with in respect of:

(a) satisfactory performance of each generator throughout a run at full rated load;

(b) temperature of joint, connections, circuit-breakers and fuses;

(c) the operation of engine governors, synchronizing devices, overspeed trips, reverse-current, reverse-power and over-current trips and other safety devices;

(d) voltage regulation of every generator when full rated load is suddenly thrown off and when starting the largest motor connected to the system;

(e) satisfactory parallel operation, and kW and KVA load sharing of all generators capable of being operated in parallel at all loads up to normal working load;

(f) alarm sound pressure levels;

(g) all essential and other important equipment are to be operated under service conditions, though not necessarily at full load or simultaneously, for a sufficient length of time to demonstrate that they are satisfactory.

20.2.5 Voltage drop is to be measured, where necessary, to verify that this is not in excess of that specified in 1.7 or 19.9.

20.2.6 It is to be demonstrated by practical tests that the Rules have been complied with in respect of fire, crew and passenger emergency and craft safety systems.

20.2.7 On completion of the general emergency alarm system and public address system tests, the Surveyor is to be provided with two copies of the test schedule, detailing the measured sound pressure levels. Such schedules are to be signed by the Surveyor and the Builder.

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RULES AND REGULATIONS FOR THE CLASSIFICATION OF SPECIAL SERVICE CRAFT

FIRE PROTECTION, DETECTION AND EXTINCTION

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PART 17

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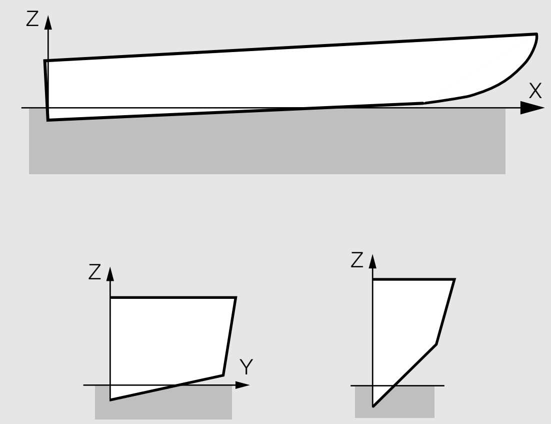
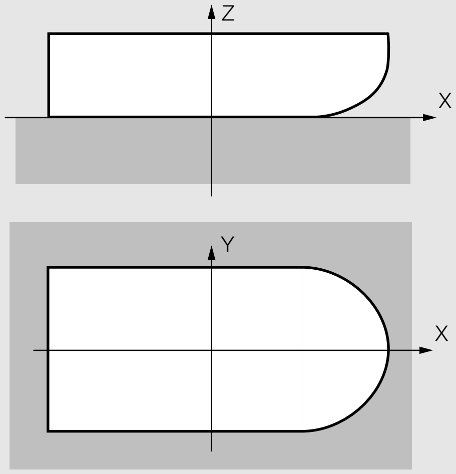
DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

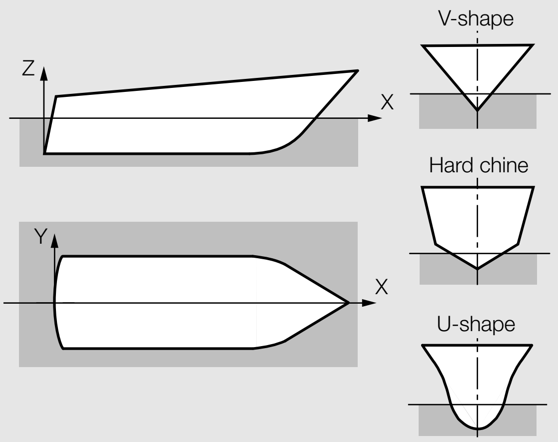
PLANING CRAFT



HOVERCRAFT



DISPLACEMENT CRAFT



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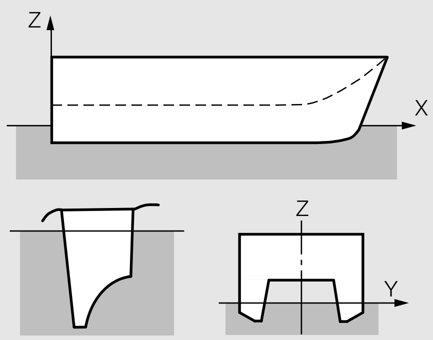

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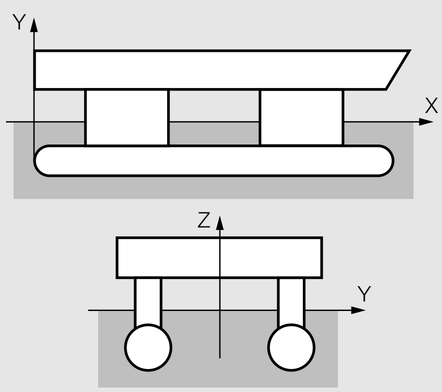
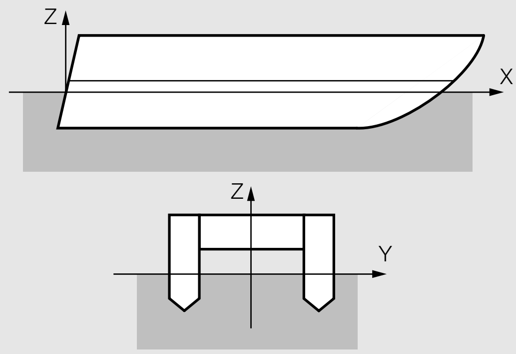
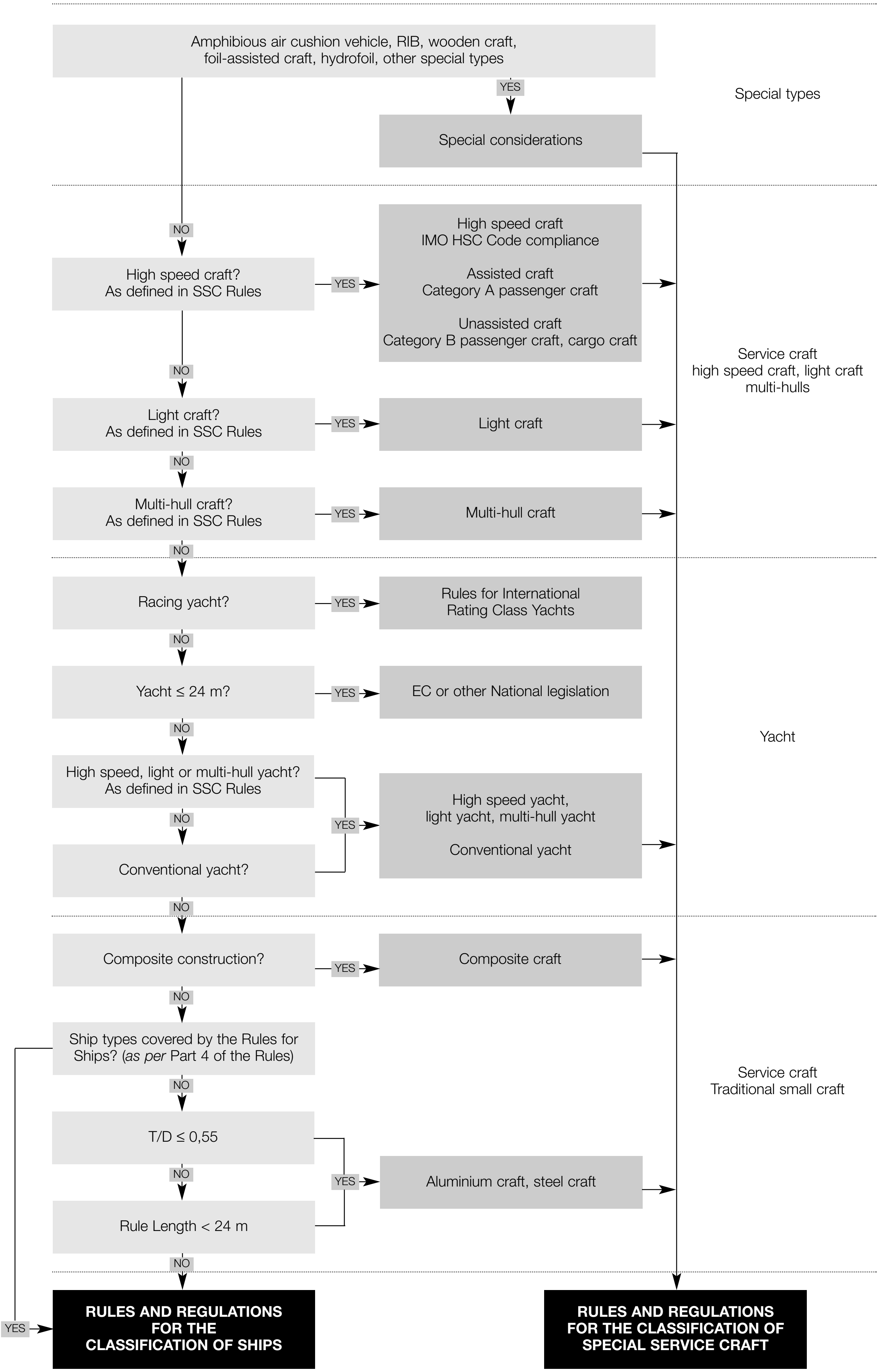


CATAMARAN



DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



Chapter Contents Part 17

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Section 1 General requirements

1.1 Application

1.1.1 The requirements of this Part apply to yachts with an overall length, L_{OA} (as defined in Pt 3, Ch 1,6.2.4) of 24 m or greater, 3000 gross registered tonnage or less, and intended for the carriage of 12 passengers or less, and service craft (*see also* 1.1.2(c)) built in accordance with these Rules.

1.1.2 Consideration will be given to the acceptance of fire safety measures:

(a) which have been prescribed and approved by the Government of the flag state;
(b) where the arrangements are considered equivalent to those required by these Rules as a result of risk assessment studies; or
(c) where the arrangements are considered acceptable compared to those required by these Rules, due cognisance having been taken of any restricted service limits.

1.1.3 Special consideration, consistent with the fire hazard involved, will be given to construction or arrangements not covered by this Chapter.

1.1.4 High speed cargo craft of 500 gross tons and over on international voyages and high speed passenger craft on international voyages are to be provided with the fire safety measures required by the *International Convention for the Safety of Life at Sea, 1974* as amended (SOLAS 74), Chapter X – Safety Measures for High Speed Craft (*International Code of Safety for High Speed Craft*).

1.1.5 High speed cargo craft of 500 gross tons and over employed on national voyages and high speed passenger craft employed on national voyages are to comply with the fire safety measures of the Government of the flag state.

1.1.6 High speed cargo craft of less than 500 gross tons employed on national or international voyages are to comply with the fire safety measures of the Government of the flag state.

1.1.7 It is the responsibility of the Government of the flag state to give effect to the fire safety measures of 1.1.4, 1.1.5 and 1.1.6. However, LR will undertake to do this in cases where:

(a) Contracting Governments have authorized LR to apply the requirements of SOLAS 74 and issue the appropriate certification on their behalf; or
(b) the Government of the flag state is not a signatory to SOLAS 74; or
(c) the craft is to be classed for restricted or special service in national waters and the Government of the flag state has no national requirements.

1.1.8 When implementing the provisions of 1.1.7, LR will apply the fire safety measures required by SOLAS 74 Chapter X – Safety Measures for High Speed Craft (*International Code of Safety for High Speed Craft*). However, due consideration will be given to arrangements deemed to provide an equivalent level of fire safety, taking due cognisance of the circumstances of the restricted or special service.

1.2 Submission of plans and information

1.2.1 The plans and information detailed in 1.2.2 to 1.2.4, where applicable, are to be submitted at least in triplicate for approval, together with all additional information such as gross tonnage and number of passengers/guests.

1.2.2 For fire protection, the following plans and information are to be submitted:

(a) Structural fire protection plan showing extent of materials used in construction, steel, aluminium, or alternative forms of construction, together with details of the thermal characteristics of the alternative forms of construction that include the temperature at which the material starts to lose its strength, and proposals for protection, etc.
(b) A general arrangement plan showing the main fire zones, escape stairways and the fire compartmentation bulkheads and decks within the main fire zones, including engine rooms, galleys, bonded stores, paint stores, navigating bridge, radio room, fire-fighting control room, emergency generator rooms and battery locker, helicopter arrangements, including re-fuelling and petrol stowage arrangements.
(c) A plan showing the details of construction of the fire protection bulkheads and decks and particulars of any surface laminates employed.
(d) Copies of Certificates of Approval by National Authorities and Fire Test Reports in respect of all ‘A’ and ‘B’ Class fire divisions, non-combustible materials and materials having low flame-spread characteristics, etc., which are to be used but have not been approved by LR. Copies of Certificates issued by other recognised approval bodies may be submitted for consideration.
(e) A ventilation plan showing ducts and any dampers in them, closing appliances and the position of the controls for stopping the system.
(f) A plan showing the fire detection and alarm system.
(g) A plan showing the remote control system for fire doors, if applicable.
(h) A fire control plan meeting the requirements of Ch 4,5.

1.2.3 For fire-extinguishing the following plans are to be submitted:

(a) A general arrangement plan showing the disposition of all the fire-fighting equipment including the fire main, the fixed fire-extinguishing systems; the disposition of the portable and non-portable extinguishers and the types used; and the position and details of the firemen’s outfits.

(b) A plan showing the layout and construction of the fire main, including the main and emergency fire pumps, isolating valves, pipe sizes and materials, and the cross connections to any other system.
(c) A plan showing details of each fixed fire-fighting system, including calculations for the quantities of the media used and the proposed rates of application.

1.2.4 Fire-control plans as required by Ch 4,5 are to be submitted.

■ *Section 2* Definitions

2.1 Materials

2.1.1 **Non-combustible material** means a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750°C, according to an established test procedure, *see* IMO *International Code for Application of Fire Test Procedures* (FTP Code), Annex 1, Part 1. Any other material is a **combustible material**.

2.1.2 **Steel or other equivalent material**. Where the words 'steel or other equivalent material' occur, 'equivalent material' means any non-combustible material which, by itself, or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable fire exposure to the standard fire test (e.g. aluminium with appropriate insulation).

2.1.3 **Alternative forms of construction** means any combustible material may be accepted if it can be demonstrated that the material, which by itself or due to insulation provided has structural and fire integrity properties equivalent to 'A' or 'B' class divisions, or steel, as applicable, at the end of the applicable fire exposure to the standard fire test.

2.2 Fire test

2.2.1 A **standard fire test** is one in which the specimens of the relevant bulkheads and decks are exposed in a test furnace to temperatures corresponding approximately to the standard time-temperature curve. The test methods are to be in accordance with the IMO FTP Code, Annex 1, Part 3.

2.3 Flame spread

2.3.1 **Low flame spread** means that the surface thus described will adequately restrict the spread of flame, having regard to the risk of fire in the spaces concerned, this being determined by an acceptable test procedure, *see* IMO FTP Code, Annex 1, Part 5.

2.3.2 **Not readily ignitable** means that the surface thus described will not continue to burn for more than 20 seconds after the removal of a suitable impinging test flame.

2.4 Ship divisions and spaces

2.4.1 **'A' Class divisions** are those divisions formed by bulkheads and decks, and:
(a) Are to be constructed of steel or other equivalent material.
(b) Are to be suitably stiffened.
(c) Are to be so constructed as to be capable of preventing the passage of smoke and flame up to the end of the one-hour standard fire test, *see* 2.2.1.
(d) Are to be insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180°C above the original temperature, within the time listed below:

Class 'A-60'	60 minutes.
Class 'A-30'	30 minutes.
Class 'A-15'	15 minutes.
Class 'A-0'	0 minutes.

(e) May be required to demonstrate that they meet the above requirements for integrity and temperature rise, through a test.

2.4.2 **'B' Class divisions** are those divisions formed by bulkheads, decks, ceilings or linings and:
(a) Are to be so constructed as to be capable of preventing the passage of flame to the end of the first half hour of the standard fire test, *see* IMO FTP Code, Annex 1, Part 3.
(b) Are to be insulated such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature at any one point, including any joint, rise more than 225°C above the original temperature, within the time listed below:

Class 'B-15'	15 minutes.
Class 'B-0'	0 minutes.

(c) Are to be constructed of approved non-combustible materials and all materials entering into the construction and erection of 'B' Class divisions are to be non-combustible, except where permitted by other requirements of this Chapter.
(d) May be required to ensure that they meet the above requirements for integrity and temperature rise through a test of a prototype division.

2.4.3 **'C' Class divisions** are divisions to be constructed of approved non-combustible materials. They need to meet neither requirements relative to the passage of smoke and flame nor limitations relative to the temperature rise. Combustible veneers are permitted provided they meet other requirements of this Chapter.

2.4.4 **Continuous 'B' Class ceilings or linings** are those 'B' Class ceilings or linings which terminate only at an 'A' or 'B' Class division.

2.4.5 **Accommodation spaces** are those spaces used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, games and hobbies rooms, pantries containing no cooking appliances and similar spaces.

2.4.6 **Service spaces** are those used for galleys, pantries containing cooking appliances, stores, mail and specie rooms, store rooms, lockers, workshops other than those forming part of the machinery spaces and similar spaces and trunks to such spaces.

2.4.7 **Cargo spaces** are all spaces used for cargo (including cargo oil tanks) and trunks to such spaces.

2.4.8 **Machinery spaces of Category A** are those spaces and trunks to such spaces which contain:

(a) internal combustion machinery used for main propulsion; or
(b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
(c) any oil-fired boiler or oil fuel unit.

2.4.9 **Machinery spaces** are all machinery spaces of Category 'A' and all other spaces containing propelling machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air conditioning machinery, and similar spaces; and trunks to such spaces.

2.4.10 **Control stations** are those spaces in which the craft's radio or main navigating equipment or the emergency source of power is located or where the fire recording or fire-control equipment is centralized.

2.4.11 **Cargo area** is that part of the craft that contains cargo tanks, slop tanks and cargo pump rooms including pump rooms, cofferdams, ballast and void spaces adjacent to cargo tanks and also deck areas throughout the entire length and breadth of the part of the craft over the above-mentioned spaces.

2.4.12 **Main vertical zones** are those sections into which the hull, superstructure and deck houses are divided by 'A' Class divisions, the mean length and width of which on any one deck does not, in general, exceed 48 m.

2.5 Equipment

2.5.1 **Oil fuel unit** is the equipment used for the preparation of oil fuel for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 1,8 bar (1,8 kgf/cm^2) gauge.

2.6 Craft types

2.6.1 For the purpose of this Part the definitions of craft types given in 2.6.2 and 2.6.3 apply.

2.6.2 A **passenger craft** is a craft which carries more than twelve passengers.

2.6.3 A **yacht** is a recreational craft used for sport or pleasure and may be propelled mechanically, by sail or by a combination of both.

Section 1 General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to service craft built in accordance with these Rules.

1.1.2 Where service craft incorporate fire hazards not covered in this Part, appropriate fire protection, detection and extinction arrangements are to be provided. Details are to be submitted for approval.

Section 2 Fire safety measures for service craft

2.1 General

2.1.1 Table 2.2.1 is a guide to the major requirements of this Section. The Table is intended as a quick reference to the requirements and is not to be used in isolation when designing the fire safety arrangements.

2.2 Forms of construction – Structure

2.2.1 The hull, superstructure, structural bulkheads, decks and deckhouses may be constructed of steel, other equivalent material, *see* Ch 1,2.1.2, or be of alternative forms of construction, *see* Ch 1,2.1.3.

2.2.2 The structure in way of Category 'A' machinery spaces, galleys containing appliances of significant fire risk, *see* 2.4.2, and other high risk areas is to be protected such that the material by itself or due to insulation provided can maintain its required strength at the end of 30 minutes exposure to the standard fire test.

2.2.3 Details of the method of construction, supported by calculations and/or fire test data, demonstrating compliance with 2.2.2, are to be submitted.

2.2.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200ºC above the ambient temperature at any time during the specified fire exposure.

Table 2.2.1 General fire protection, detection and extinction requirements

Form of construction, *see* 2.2	Steel or equivalent, or alternative forms of construction may be accepted, subject to requirements in high fire risk areas
Passive fire protection, *see* 2.3 to 2.6	Category 'A' machinery spaces: • For craft >150 gross tons: A-30/A-0 • For craft <150 gross tons: A-0 Galleys: • For craft >50 gross tons: B-15
Means of escape, *see* 2.7: • Machinery spaces • Accommodation, etc.	} 2
Fixed fire detection system, *see* 2.13	• Fitted in all machinery spaces • Fitted in stairways, service spaces, machinery spaces, control stations and accommodation spaces of craft >50 gross tons with sleeping accommodation
Fire pumps, *see* 2.14	• 1 fixed power pump + 1 portable pump • For craft <150 gross tons: 1 portable pump
Fire-extinguishing arrangements in machinery spaces, *see* 2.15	• A fixed fire-extinguishing system • A minimum of 2, but need not exceed 5 portable foam extinguishers or equivalent
Portable fire-extinguishers in accommodation, *see* 2.18	Sufficient to ensure that at least one will be readily available in every compartment

2.2.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the specified fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.2.6 For structures in contact with sea-water, the required insulation should extend to at least 300 mm below the lightest waterline, *see also* 2.6.1.

2.3 Forms of construction – Fire divisions

2.3.1 Fire divisions required by 2.4 are to be constructed in accordance with the remaining paragraphs of this sub-Section.

2.3.2 Fire divisions using steel equivalent or alternative forms of construction may be accepted if it can be demonstrated that the material by itself, or due to insulation provided, has the fire resistance properties equivalent to 'A' or 'B' class divisions.

2.3.3 Insulation required by 2.3.2 is to be such that the temperature of the structural core does not rise above the point at which the structure would begin to lose its strength at any time during the applicable exposure to the standard fire test. For 'A' class divisions, the applicable exposure is 60 minutes, and for 'B' Class divisions, the applicable exposure is 30 minutes.

2.3.4 For aluminium alloy structures the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the applicable fire exposure.

2.3.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the applicable fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the Rules for Materials.

2.4 Structural fire protection

2.4.1 Category 'A' machinery spaces are to be enclosed by A-30 Class divisions where adjacent to accommodation spaces, or control positions and A-0 Class divisions elsewhere. For craft below 150 gross tons, Category 'A' machinery spaces are to be enclosed by A-0 Class divisions, regardless of adjacent space use.

2.4.2 For craft greater than 50 gross tons, galleys are to be enclosed by B-15 Class divisions unless the cooking appliances contained therein have an insignificant fire risk.

(a) For the purposes of this Chapter, coffee automats, toasters, dishwashers, microwave ovens, water boilers and similar appliances each with a maximum power of 5 kW may be regarded as having an insignificant fire risk. Electrically-heated cooking plates and hot plates for keeping food warm, each of them having a maximum power of 2 kW and a surface temperature not above 150°C may also be regarded as having insignificant fire risk. If spaces containing this equipment are lockable, then means of cutting-off the power to the space are to comply with Pt 16, Ch 2,16.6.7.

(b) Other equipment such as fat fryers, open flame cookers, etc., are to be regarded as having a significant fire risk.

2.4.3 Openings in 'A' Class divisions are to be provided with permanently attached means of closing that are to be at least as effective for resisting fires as the divisions in which they are fitted.

2.4.4 Interior stairways serving machinery spaces, accommodation spaces, service spaces or control stations are to be of steel or other equivalent material.

2.4.5 Doors are to be self-closing in way of Category 'A' machinery spaces.

2.4.6 Where 'A' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for girders, beams or other structural members, arrangements are to be made to ensure that the fire resistance is not impaired.

2.4.7 Where the structure or 'A' Class divisions are required to be insulated, it is to be ensured that the heat from a fire is not transmitted through the intersections and terminal points of the divisions or penetrations to uninsulated boundaries. Where the insulation installed does not achieve this, arrangements are to be made to prevent this heat transmission by insulating the horizontal and vertical boundaries or penetrations for a distance of 450 mm.

2.5 Materials

2.5.1 Paints, varnishes and other finishes used on exposed interior surfaces are not to be capable of producing excessive quantities of smoke, toxic gases or vapours and are to be of the low flame spread type. Reference is also to be made to the IMO FTP Code, Annex 1, Parts 2 and 5.

2.5.2 Except in refrigerated compartments of service space, all insulation (e.g. fire and comfort) is to be of non-combustible materials.

2.5.3 Pipes penetrating 'A' Class divisions are to be of approved materials having regard to the temperature such divisions are required to withstand.

2.5.4 Pipes conveying oil or combustible liquids through accommodation and service spaces are to be of approved materials having regard to the fire risk.

2.5.5 Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges, and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.

2.5.6 Primary deck coverings within accommodation spaces, service spaces and control stations are to be of a type that will not readily ignite, or give rise to toxic or explosive hazards at elevated temperatures. Reference is also to be made to the IMO FTP Code, Annex 1, Parts 2 and 6.

2.5.7 Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings for cold service systems need not be non-combustible, but they are to be kept to the minimum quantity practicable and their exposed surfaces are to have low flame spread characteristics.

2.5.8 All waste receptacles are to be constructed of non-combustible materials with no openings in the sides or bottom.

2.6 Surface of insulation

2.6.1 In spaces where penetration of oil products is possible, the surface of insulation is to be impervious to oil or oil vapours. Insulation boundaries are to be arranged to avoid immersion in oil spillages.

2.7 Means of escape

2.7.1 Stairways, ladders and corridors serving crew spaces and other spaces to which the crew normally have access are to be arranged so as to provide ready means of escape to a deck from which disembarkation may be effected.

2.7.2 Where reasonable and practicable, and having regard to the number of crew and size of space, at least two means of escape, as widely separated as possible, are to be provided from each section of accommodation spaces, service spaces and control stations:

(a) The normal means of access to the accommodation and service spaces below the open deck is to be arranged so that it is possible to reach the open deck without passing through intervening spaces containing a possible source of fire.

(b) The second means of escape may be through portholes, or hatches of adequate size, leading to the open deck.

(c) No dead-end corridors having a length of more than 7 m will be accepted. A 'dead-end corridor' is a corridor or part of a corridor from which there is only one escape route.

2.7.3 At least two means of escape are to be provided from machinery spaces, except where the small size of the machinery space makes it impractical. Escape is to be by steel ladders that are as widely separated as possible.

2.8 Ventilation systems

2.8.1 Ventilation fans are to be capable of being stopped, and main inlets and outlets of ventilation systems closed, from outside the spaces being served, *see also* Pt 16, Ch 2,16.6.

2.8.2 Ventilation ducts for Category 'A' machinery spaces and exhaust ducts for galleys of significant fire risk are not to pass through accommodation spaces, service spaces or control stations unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.3 Ventilation ducts for accommodation spaces, service spaces or control stations are not to pass through Category 'A' machinery spaces unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.4 Store-rooms containing highly flammable products are to be provided with ventilation arrangements that are separate from other ventilation systems. Ventilation is to be arranged to prevent the build-up of flammable vapours at high and low levels. The inlets and outlets of ventilators are to be positioned so that they do not draw from or vent into an area which would cause undue hazard, and are to be fitted with spark arrestors.

2.8.5 Ventilation systems serving Category 'A' machinery spaces are to be independent of systems serving other spaces.

2.8.6 All enclosed spaces containing free-standing fuel tanks are to be ventilated independently of systems serving other spaces.

2.8.7 Ventilation is to be provided to prevent the accumulation of dangerous concentrations of flammable gas that may be emitted from batteries. The requirements of Pt 16, Ch 2,11.5 are to be complied with.

2.8.8 Ventilation openings may be fitted in and under the lower parts of cabin and public space doors in corridor bulkheads. Ventilation grills are to be of non-combustible material. The total net area of any such openings is not to exceed 0,05 m^2. Bridging ducts are not allowed in fire divisions.

2.8.9 For additional requirements for the ventilation of domestic gaseous fuel, *see* 2.11.

2.9 Fuel arrangements

2.9.1 In service craft in which oil fuel is used, the arrangements for the storage, distribution and utilization of the oil fuel are to be such as to ensure the safety of the service craft and persons on board. For details, *see* Pt 15, Ch 3.

2.9.2 Oil fuel tanks situated within the boundaries of Category 'A' machinery spaces are not to contain oil fuel having a flashpoint of less than 60°C.

2.9.3 Oil fuel, lubricating oil and other flammable oils are not to be carried in fore peak tanks.

2.10 Special arrangements in machinery spaces and, where necessary, other spaces

2.10.1 Openings are to be provided with closing appliances constructed so as to maintain the fire integrity of the machinery space boundaries.

2.10.2 The type of equipment installed and the layout of the craft are to take account of the risk and spread of fire. Special attention is to be paid to the surroundings of open flame devices, hot areas and main and auxiliary machinery, oil and fuel overflows, and uncovered oil and fuel pipes.

2.10.3 Fuel filling, storage, venting and supply systems are to be installed so as to minimize the risk of fire and explosion.

2.10.4 Machinery components and accessories that require frequent maintenance and inspection are to be readily accessible.

2.10.5 Windows are not to be fitted in machinery space boundaries. This does not preclude the use of glass in control rooms within the machinery spaces.

2.10.6 In Category 'A' machinery spaces means of control are to be provided for:

(a) closure of openings which normally allow exhaust ventilation, and closure of ventilator dampers;
(b) permitting the release of smoke;
(c) stopping ventilating fans; and
(d) stopping forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps and other similar fuel pumps.

2.10.7 The controls required in 2.10.6 are to be located outside the space concerned, in a position where they will not be cut off in the event of fire in the space they serve. Such controls and the controls for any required fire-extinguishing system are to be situated at one control position or grouped in as few positions as possible. Such positions are to have a safe access from the open deck. *See also* Pt 15, Ch 3,4.5.1 and 4.9.2.

2.11 Arrangements for gaseous fuel for domestic purposes

2.11.1 Where gaseous fuel is used for domestic purposes, the arrangements for the storage, distribution and utilisation of the fuel are to be such that, having regard to the hazards of fire and explosion which the use of such fuel may entail, the safety of the service craft and the persons onboard is preserved. The installation is to be in accordance with recognised National or International Standards.

2.11.2 Storage lockers for gas cylinders are to be provided with:

(a) effective ventilation;
(b) an outward-opening door accessible directly to the open deck; and
(c) gas-tight boundaries, including doors and other means of closing any openings therein, which form boundaries between such lockers and adjoining spaces.

2.11.3 Arrangements for storage on open deck will be specially considered.

2.12 Space heaters

2.12.1 Space heaters, if used, are to be fixed in position and so constructed as to reduce fire risks to a minimum. The design and location of these units are to be such that clothing, curtains or other similar materials cannot be scorched or set on fire by heat from the unit.

2.13 Fixed fire detection and fire-alarm systems

2.13.1 A fixed fire detection and fire-alarm system is to be installed in all Category 'A' machinery spaces and is to comply with the requirements of Pt 16, Ch 1,2.8.

2.13.2 In craft over 50 gross tons, where sleeping accommodation is provided on board, a fixed fire detection and fire-alarm system is to be installed in all stairways, service spaces, machinery spaces, control stations and accommodation spaces (except toilets, bathrooms, void spaces, etc.). The fixed fire detection and fire-alarm system is to be installed in accordance with Ch 4,2.

2.14 Fire pumps and fire main system

2.14.1 **Application**:

(a) Every service craft is to be provided with a fire pump(s), fire mains, hydrants and hoses as required by this Chapter.
(b) For very small service craft, where it is not considered possible to fit a fire pump, the arrangements will be specially considered.

2.14.2 **Capacity of fire pumps**. The capacity of the fixed main fire pump(s) is not to be less than:

$$Q = (0{,}15\,(L_R\,(B + D))^{1/2} + 2{,}25)^2$$

but need not exceed 25 m^3/hour.

where

B = greatest moulded breadth of craft, in metres
D = moulded depth to bulkhead deck, in metres
L_R = Rule length of craft, as defined in Pt 3, Ch 1,6.2.1, in metres
Q = total capacity in m^3/hours.

2.14.3 **Fire pumps**:

(a) In service craft of 150 tons gross or more, a minimum of one fixed power pump and one portable pump, complying with 2.14.4, are to be provided.
(b) For service craft of less than 150 tons gross, one portable pump or alternative as required by 2.14.4, is to be provided.
(c) Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil, and that, if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable changeover arrangements are fitted.
(d) In service craft classed for navigation in ice, the fire pump sea inlet valves are to be provided with ice clearing arrangements, *see* Pt 1, Ch 2,3.8.1.
(e) Relief valves are to be provided in conjunction with any fire pumps if the pump is capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.
(f) Where centrifugal pumps are provided in order to comply with this Section, a non-return valve is to be fitted in the pipe connecting each pump to the fire main.

2.14.4 **Portable fire pumps**:

(a) Except for electric pumps, which will be specially considered, portable fire pumps are to comply with the following:

(i) The pump is to be self priming.

(ii) The suction head in operation is not to exceed 4,5 m.

(iii) The portable fire pump is to be fitted with a length of discharge hose and nozzle capable of maintaining a pressure sufficient to produce a jet throw of at least 12 m, or that required to enable a jet of water to be directed on any part of the engine room or the exterior boundary of the engine room and casing, whichever is the greater. The jet throw required need not exceed the length of the craft.

(iv) The pump set is to have its own fuel tank of sufficient capacity to operate the pump for three hours.

(v) Details of the fuel type and storage location are to be submitted. If the fuel type has a flashpoint below 60ºC, further consideration will be given to the fire safety aspects.

(vi) The pump set is to be stored in a secure, safe and enclosed space, accessible from open deck and clear of the Category 'A' machinery space.

(vii) The pump set is to be easily moved and operated by two persons and be readily available for immediate use.

(viii) Arrangements are to be provided to secure the pump at its anticipated operating position(s).

(ix) The overboard suction hose is to be non-collapsible and of sufficient length to cater for the craft's motion under all operational conditions. A suitable strainer is to be fitted at the inlet end of the hose.

(x) Any diesel-driven power source for the pump is to be capable of being readily started in its cold condition down to a temperature of 0ºC by hand (manual) cranking.

(b) If it is not possible to comply with the requirements of 2.14.4(a), an additional fixed fire pump will be required, which is to comply with the following:

(i) The pump, its source of power and sea connection are to be located in accessible positions outside the Category 'A' machinery space, or in a different space to the main fire pump, if the main fire pump is located outside the Category 'A' machinery space. In the case of craft defined in 2.14.3(b), the pump may be situated in the Category 'A' machinery space, if so desired.

(ii) The sea valve is to be capable of being operated from a position near the pump.

(iii) The space where the fire pump prime mover is located is to be illuminated from the emergency source of electrical power, except for craft defined in 2.14.3(b), and is to be well ventilated.

(iv) If the pump is required to supply water for a fixed fire-extinguishing system in the space where the main fire pumps are situated, it is to be capable of simultaneously supplying water to this system and the fire main at the required rates.

(v) The pump may also be used for other suitable purposes, subject to approval in each case.

(vi) The pressure and quantity of water delivered by the pump is to be sufficient to produce a jet of water at any nozzle of not less than 12 m.

(vii) In the case of craft defined in 2.14.3(b), a fire main, hydrants and hoses are to be installed in accordance with 2.14.5 to 2.14.10.

(c) Means to illuminate the stowage area of the portable pump and its necessary areas of operation are to be provided from the emergency source of electrical power.

(d) If preferred, a pump complying with 2.14.4(b) may be fitted instead of a portable pump complying with 2.14.4(a).

2.14.5 **Fire main**:

(a) The diameter of the fire main is to be based on the required capacity of the fixed main fire pump(s). The diameter of the water service pipes are to be sufficient to ensure an adequate supply of water for the operation of at least one fire-hose.

(b) The wash deck line may be used as a fire main provided that the requirements of this Section are satisfied.

(c) All exposed water pipes for fire-extinguishing are to be provided with drain valves for use in frosty weather. The valves are to be located where they will not be damaged by cargo.

2.14.6 **Pressure in the fire main**. When the fixed main fire pump, or the fire pump described in 2.14.4(b), is delivering the quantity of water required by 2.14.2 through the fire main, fire hoses and nozzles, the pressure maintained at any hydrant is to be sufficient to produce a jet throw at any nozzle of not less than 12 m.

2.14.7 **Number and position of hydrants**. The number and position of the hydrants are to be such that at least one jet of water is to reach any part normally accessible to the crew while the service craft is being navigated and any part of any cargo space when empty. Furthermore, such hydrants are to be positioned near the accesses to the protected spaces. At least one hydrant is to be provided in each machinery space.

2.14.8 **Pipes and hydrants**:

(a) Materials readily rendered ineffective by heat are not to be used for fire mains. Where steel pipes are used, they are to be galvanized internally and externally. Cast iron pipes are not acceptable. The pipes and hydrants are to be so placed that the fire-hoses may be easily coupled to them. The arrangements of pipes and hydrants is to be such as to avoid the possibility of freezing. In service craft where deck cargo may be carried, the positions of the hydrants are to be such that they are always readily accessible and the pipes are to be arranged, as far as practicable, to avoid risk of damage by such cargo. Unless one hose and nozzle is provided for each hydrant in the service craft, there is to be complete interchangeability of hose couplings and nozzles.

(b) A valve is to be fitted at each fire hydrant so that any fire-hose may be removed while the fire pumps are at work.

(c) Where an additional fixed fire pump is fitted in accordance with 2.14.4(b) or 2.14.4(d):
  (i) An isolating valve is to be fitted in the fire main so that all the hydrants in the service craft, except those in the Category 'A' machinery space containing the main fire pump, can be supplied with water by the additional fixed fire pump. The isolating valve is to be located in an easily accessible and tenable position outside the Category 'A' machinery space; and
  (ii) The fire main is not to re-enter the machinery space downstream of the isolating valve.

2.14.9 **Fire-hoses**:
(a) Fire-hoses are to be of approved non-perishable material. The hoses are to be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length, in general, is not to exceed 18 m. Each hose is to be provided with a nozzle and the necessary couplings. Fire-hoses, together with any necessary fittings and tools, are to be kept ready for use in conspicuous positions near the water service hydrants or connections.
(b) The number of fire-hoses to be provided, each complete with couplings and nozzles, is to be one for each 15 m length of the service craft, or part thereof, but need not exceed the number of hydrants provided. This number does not include any hoses required in any engine room. If necessary, the number of hoses is to be increased so as to ensure that hoses in sufficient numbers are available and accessible at all times.

2.14.10 **Nozzles**:
(a) For the purpose of this Chapter, standard nozzle sizes are to be 12 mm, 16 mm or 19 mm, or as near thereto as possible, so as to make full use of the maximum discharge capacity of the fire pump(s).
(b) For accommodation and service spaces, the nozzle size need not exceed 12 mm.
(c) The size of nozzles intended for use in conjunction with a portable fire pump need not exceed 12 mm.
(d) All nozzles are to be of an approved dual purpose type (i.e. spray/jet type) incorporating a shut-off.

2.15 Fire-extinguishing arrangements in Category 'A' machinery spaces

2.15.1 Except where provided for in 2.15.2, Category 'A' machinery spaces are to be provided with:
(a) one of the fixed fire-extinguishing systems given in Ch 4,3; and
(b) at least two portable foam extinguishers or equivalent, *see* Ch 4,6.3.2. Where internal combustion machinery is installed, an additional portable extinguisher is to be provided for every 375 kW of power output, but the total number of such additional extinguishers need not exceed five.

2.15.2 Where the size of the machinery space precludes access under normal operating conditions, provision is to be made such that a manually-released extinguishing medium, of a type allowed in Chapter 4, can be remotely discharged into the space. Such arrangements may utilise a portable extinguisher of adequate size. Details of the arrangements with supporting calculations are to be submitted for approval.

2.16 Fire-extinguishing appliances in other machinery spaces

2.16.1 Where a fire hazard exists in any machinery space for which no specific provisions for fire-extinguishing appliances are prescribed in 2.15 and 2.17, there is to be provided in, or adjacent to, that space a satisfactory number of approved portable fire-extinguishers or other approved means of fire-extinction.

2.17 Machinery spaces in craft which are constructed mainly or wholly of alternative forms of construction

2.17.1 Machinery spaces in craft which are constructed mainly or wholly with alternative forms of construction that contain internal combustion machinery, are to comply with the fire-extinguishing requirements for Category 'A' machinery spaces, *see* 2.15.1.

2.18 Fixed fire-extinguishing systems not required by this Chapter

2.18.1 Where a fixed fire-extinguishing system not required by this Chapter is installed, the arrangement is to comply with the relevant requirements of this Chapter.

2.19 Portable fire-extinguishers

2.19.1 All portable fire-extinguishers are to comply with the requirements of Ch 4,6.

2.19.2 The portable fire-extinguishers are to be stowed in readily accessible positions.

2.19.3 One of the portable fire-extinguishers intended for use in any space is to be stowed near the entrance to that space.

2.19.4 At least one portable fire-extinguisher is to be located so that it can easily be reached from the main steering position of the craft.

2.19.5 Accommodation spaces, service spaces and control stations are to be provided with a sufficient number of portable fire-extinguishers to ensure that at least one extinguisher will be readily available for use in every compartment.

2.19.6 Where cooking facilities are provided a portable fire-extinguisher of a type appropriate to the energy source used is to be located in a position readily accessible for use in the event of a fire.

2.20 Fire blanket

2.20.1 A fire blanket is to be installed in all galleys.

2.21 Protection of paint lockers and flammable liquid lockers

2.21.1 Paint lockers and flammable liquid lockers with a deck area 4 m^2 or over are to be provided with a fixed fire-extinguishing system enabling the crew to extinguish a fire without entering the space. One of the following systems is to be provided:

- A carbon dioxide system designed for 40 per cent of the gross volume of the space.
- A dry powder system designed to discharge 0,5 kg powder per cubic metre of gross volume of the space.
- A water spray system designed to give a coverage of 5 litres per square metre of deck area per minute. Water spray systems may be connected to the fire main.

2.21.2 Consideration will be given to the acceptance of other arrangements which provide equivalent protection.

2.21.3 Lockers having a deck area of less than 4 m^2 may be protected by carbon dioxide or dry powder portable extinguishers located near the entrance to the locker.

2.22 Arrangements where deep-fat cooking equipment is installed

2.22.1 Where deep-fat cooking equipment is installed in high speed craft, all installations are to be fitted with:

(a) an automatic or manual fixed extinguishing system type approved in accordance with ISO 15371, *Ships and marine technology – Fire extinguishing systems for protection of galley deep-fat cooking equipment – Fire tests*, or an acceptable alternative National or International Standard, for protection of the deep-fat cooking equipment;

(b) a primary and back up thermostat with an alarm to alert the operator in the event of failure of either thermostat;

(c) means to automatically shut off the deep-fat cooking equipment electrical power upon activation of the fire-extinguishing system;

(d) an alarm for indicating operation of the fire-extinguishing system in the galley where the equipment is installed; and

(e) controls for manual operation of the fire-extinguishing system which are clearly labelled for ready use by the crew.

Control and electrical engineering arrangements are to be in accordance with the requirements of Pt 16, Ch 1 and Ch 2, as applicable.

2.23 Helicopter decks

2.23.1 The requirements of IMO Resolution A.855(20) are to be complied with having due regard to the hazards involved.

2.23.2 If a helicopter hangar is not provided and if two fireman’s outfits are supplied as per 2.24.1, then the fireman’s outfits required by IMO Resolution A.855(20) need not be provided.

2.24 Fireman's outfit

2.24.1 All service craft of 350 gross tons or more and having enclosed spaces which are normally accessible, are to carry at least two fireman's outfits complying with the requirements of Ch 4,4.

2.25 Fire-control plans

2.25.1 Fire-control plans are to meet the requirements of Ch 4,5.

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to yachts with an overall length, L_{OA} (as defined in Pt 3, Ch 1,6.2.4) of 24 m or greater built in accordance with the Rules.

1.1.2 Where yachts incorporate fire hazards not covered in this Part, appropriate fire protection, detection and extinction arrangements are to be provided. Details are to be submitted for approval.

1.1.3 For yachts with an overall length of 24 m or more, and less than 500 gt, the fire safety measures are to comply with Section 2.

1.1.4 For yachts 500 gt or more, the fire safety measures are to comply with Section 3.

■ *Section 2* Fire safety measures for yachts of overall length greater than 24 m but less than 500 gt

2.1 General

2.1.1 Table 3.2.1 is a guide to the major requirements of this Section. The Table is intended as a quick reference to the requirements and is not to be used in isolation when designing the fire safety arrangements.

Table 3.2.1 General fire protection, detection and extinction requirements

Form of construction, *see* 2.2	Steel or equivalent, or alternative forms of construction may be accepted subject to requirements
Passive fire protection, *see* 2.3 to 2.6	• Category 'A' machinery spaces 'A-30'/'A-0' • Galleys: 'B-15' where significant fire risk • Bulkheads in escape route corridors greater than 7 m in length: 'B-0' • Stairway enclosures: 'B-0'
Means of escape, *see* 2.7 • Category 'A' machinery spaces • Accommodation, etc.	} 2
Fixed fire detection system, *see* 2.13	• Fitted in machinery spaces • Fitted in service spaces, control stations and accommodation spaces
Fire pumps, *see* 2.14	1 fixed power pump + 1 portable pump
Fire extinguishing arrangements in Category 'A' machinery spaces, *see* 2.15	• A fixed fire-extinguishing system • A minimum of 2 and maximum of 5 portable foam extinguishers or equivalent
Portable fire-extinguishers in accommodation, *see* 2.18	At least 3
Automatic sprinkler system or equivalent, *see* 2.16	Fitted in yachts >350 gross tons

2.2 Forms of construction – Structure

2.2.1 The hull, superstructure, structural bulkheads, decks and deckhouses may be constructed of steel, other equivalent material, *see* Ch 1,2.1.2, or be of alternative forms of construction, *see* Ch 1,2.1.3.

2.2.2 The structure in way of Category 'A' machinery spaces, galleys containing appliances of significant fire risk, *see* 2.4.2, and other high risk areas is to be protected such that the material by itself or due to insulation provided can maintain its required strength at the end of 30 minutes exposure to the standard fire test.

2.2.3 Details of the method of construction, supported by calculations and/or fire test data, demonstrating compliance with 2.2.2 are to be submitted.

2.2.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the specified fire exposure.

2.2.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the specified fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.2.6 For structures in contact with sea-water, the required insulation should extend to at least 300 mm below the lightest waterline, *see also* 2.6.1.

2.3 Forms of construction – Fire divisions

2.3.1 Fire divisions required by 2.4 are to be constructed in accordance with the remaining paragraphs of this sub-Section.

2.3.2 Fire divisions using steel equivalent, or alternative forms of construction may be accepted if it can be demonstrated that the material by itself, or due to insulation provided, has the fire resistance properties equivalent to 'A' or 'B' Class divisions.

2.3.3 Insulation required by 2.3.2 is to be such that the temperature of the structural core does not rise above the point at which the structure would begin to lose its strength at any time during the applicable exposure to the standard fire test. For 'A' Class divisions, the applicable exposure is 60 minutes, and for 'B' Class divisions, the applicable exposure is 30 minutes.

2.3.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the applicable fire exposure.

2.3.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the applicable fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the Rules for Materials.

2.4 Structural fire protection

2.4.1 Category 'A' machinery spaces, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are to be enclosed by 'A-30' Class divisions where adjacent to accommodation or service spaces, control positions or each other, and 'A-0' Class divisions elsewhere.

2.4.2 Galleys are to be enclosed by 'B-15' Class divisions, unless the cooking appliances contained therein have an insignificant fire risk:

(a) For the purposes of this Chapter, coffee automats, toasters, dishwashers, microwave ovens, water boilers and similar appliances each with a maximum power of 5 kW may be regarded as having an insignificant fire risk. Electrically-heated cooking plates and hot plates for keeping food warm, each of them having a maximum power of 2 kW and a surface temperature not above 150°C may also be regarded as having insignificant fire risk. If spaces containing this equipment are lockable, then means of cutting-off the power to the space are to comply with Pt 16, Ch 2,16.6.7.

(b) Other equipment such as fat fryers, open flame cookers, etc., would be regarded as having a significant fire risk.

2.4.3 Where forming escape routes, corridor bulkheads and ceilings may be constructed of combustible materials provided they have a non-combustible core such that the 'B-0' Class standard fire test criteria are met.

2.4.4 Stairways connecting spaces below the main deck to the deck above are to be protected at one level by at least 'B-0' Class divisions and self-closing doors.

2.4.5 Lift and dumbwaiter trunks are to be enclosed by at least 'B-0' Class divisions and self-closing doors.

2.4.6 Openings in 'A' and 'B' Class divisions are to be provided with permanently attached means of closing that are to be at least as effective for resisting fires as the divisions in which they are fitted.

2.4.7 Interior stairways serving machinery spaces, accommodation spaces, service spaces or control stations are to be of steel, or other equivalent material.

2.4.8 Where 'A' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for girders, beams or other structural members, arrangements are to be made to ensure that the fire resistance is not impaired.

2.4.9 Where 'B' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for the fitting of ventilation terminals, lighting fixtures and similar devices, arrangements are to be made to ensure that the fire resistance is not impaired.

2.4.10 Where the structure or 'A' Class divisions are required to be insulated, it is to be ensured that the heat from a fire is not transmitted through the intersections and terminal points of the divisions or penetrations to uninsulated boundaries. Where the insulation installed does not achieve this, arrangements are to be made to prevent this heat transmission by insulating the horizontal and vertical boundaries or penetrations for a distance of 450 mm.

2.5 Materials

2.5.1 Except in refrigerated compartments of service spaces, all insulation other than fire insulation is to be of not-readily ignitable type. Fire insulation is to be of the non-combustible type.

2.5.2 Pipes penetrating 'A' or 'B' Class divisions are to be of approved materials having regard to the temperature such divisions are required to withstand.

2.5.3 Pipes conveying oil or combustible liquids through accommodation and service spaces are to be of approved materials having regard to the fire risk.

2.5.4 Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.

2.5.5 Primary deck coverings within accommodation spaces, service spaces and control stations are to be of a type that will not readily ignite, or give rise to toxic or explosive hazards at elevated temperatures. Reference is also to be made to the IMO FTP Code, Annex 1, Parts 2 and 6.

2.5.6 Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings for cold service systems need not be non-combustible, but they are to be kept to the minimum quantity practicable and their exposed surfaces are to have low flame spread characteristics.

2.5.7 All waste receptacles are to be constructed of non-combustible materials with no openings in the sides or bottom.

2.6 Surface of insulation

2.6.1 In spaces where penetration of oil products is possible, the surface of the insulation is to be impervious to oil or oil vapours. Insulation boundaries are to be arranged to avoid immersion in oil spillages.

2.7 Means of escape

2.7.1 Stairways, ladders and corridors serving all spaces normally accessible are to be arranged so as to provide ready means of escape to a deck from which embarkation into survival craft may be effected.

2.7.2 Where reasonable and practicable, and having regard to the number of personnel involved and size of space, at least two means of escape, as widely separated as possible, are to be provided from each section of accommodation and service spaces and control stations:

(a) The normal means of access to the accommodation and service spaces below the open deck are to be arranged so that it is possible to reach the open deck without passing through intervening spaces containing a possible source of fire.

(b) Where accommodation arrangements are such that access to compartments is through another compartment, as is often the case with an Owner's suite, a second means of escape is to be provided. The second escape route is to be as remote as possible from the main escape route.

(c) This second means of escape may be through portholes, or hatches of adequate size, leading to the open deck.

(d) No dead-end corridors having a length of more than 7 m will be accepted. A 'dead-end corridor' is a corridor or part of a corridor from which there is only one escape route.

2.7.3 At least one of the means of escape from each space referred to in 2.7.2 is to be enclosed by 'B-0' Class divisions, unless it gives access directly to the open decks from the space.

2.7.4 At least two means of escape are to be provided from machinery spaces, except where the small size of the machinery space makes it impracticable. Escape is to be by steel ladders that are as widely separated as possible.

2.7.5 Lifts are not considered as forming a means of escape.

2.8 Ventilation systems

2.8.1 Ventilation fans are to be capable of being stopped, and main inlets and outlets of ventilation systems closed, from outside the spaces being served, *see* Pt 16, Ch 2,16.6.

2.8.2 Ventilation ducts for Category 'A' machinery spaces, exhaust ducts for galleys of significant fire risk, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are not to pass through accommodation spaces, service spaces or control stations unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.3 Ventilation ducts for accommodation spaces, service spaces or control stations are not to pass through Category 'A' machinery spaces, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.4 Store-rooms containing highly flammable products are to be provided with ventilation arrangements that are separate from other ventilation systems. Ventilation is to be arranged to prevent the build up of flammable vapours at high and low levels. The inlets and outlets of ventilators are to be positioned so that they do not draw from or vent into an area which would cause undue hazard, and are to be fitted with spark arresters.

2.8.5 Ventilation systems serving Category 'A' machinery spaces are to be independent of systems serving other spaces.

2.8.6 All enclosed spaces containing free-standing fuel tanks are to be ventilated independently of systems serving other spaces.

2.8.7 Ventilation is to be provided to prevent the accumulation of dangerous concentrations of flammable gas which may be emitted from batteries. The requirements of Pt 16, Ch 2,11.5 are to be complied with.

2.8.8 Ventilation openings may be fitted in and under the lower parts of cabin and public space doors in corridor bulkheads. The total net area of any such openings is not to exceed 0,05 m^2. Bridging ducts are not allowed in fire divisions.

2.8.9 For spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels, *see* 2.20.1(d). For additional requirements for the ventilation of domestic gaseous fuel, *see* 2.11.

2.9 Fuel arrangements

2.9.1 In yachts in which oil fuel is used, the arrangements for the storage, distribution and utilization of the oil fuel are to be such as to ensure the safety of the yacht and persons on board. For details, *see* Pt 15, Ch 3.

2.9.2 Oil fuel tanks situated within the boundaries of Category 'A' machinery spaces are not to contain oil fuel having a flashpoint of less than 60°C.

2.9.3 Oil fuel, lubricating oil and other flammable oils are not to be carried in fore peak tanks.

2.10 Special arrangements in Category 'A' machinery spaces and, where necessary, other machinery spaces

2.10.1 Openings are to be provided with closing appliances constructed so as to maintain the fire integrity of the machinery space boundaries.

2.10.2 The type of equipment installed and the layout of the yacht are to take account of the risk and spread of fire. Special attention is to be paid to the surroundings of open flame devices, hot areas and main and auxiliary machinery, oil and fuel overflows, and uncovered oil and fuel pipes.

2.10.3 Fuel filling, storage, venting and supply systems are to be installed so as to minimize the risk of fire and explosion.

2.10.4 Machinery components and accessories that require frequent maintenance and inspection are to be readily accessible.

2.10.5 Windows are not to be fitted in machinery space boundaries. This does not preclude the use of glass in control rooms within the machinery spaces.

2.10.6 Means of control are to be provided for:

(a) closure of openings which normally allow exhaust ventilation, and closure of ventilator dampers;
(b) permitting the release of smoke;
(c) stopping ventilating fans; and
(d) stopping forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps and other similar fuel pumps.

2.10.7 The controls required in 2.10.6 are to be located outside the space concerned, where they will not be cut off in the event of fire in the space they serve. Such controls and the controls for any required fire-extinguishing system are to be situated at one control position or grouped in as few positions as possible. Such positions are to have a safe access from the open deck. *See also* Pt 15, Ch 3,4.5.1 and 4.9.2.

2.11 Arrangements for gaseous fuel for domestic purposes

2.11.1 Where gaseous fuel is used for domestic purposes, the arrangements for the storage, distribution and utilisation of the fuel are to be such that, having regard to the hazards of fire and explosion which the use of such fuel may entail, the safety of the yacht and the persons onboard is preserved. The installation is to be in accordance with recognised National or International Standards.

2.11.2 Storage lockers for gas cylinders are to be provided with:

(a) effective ventilation;
(b) an outward-opening door accessible directly to the open deck; and
(c) gas-tight boundaries, including doors and other means of closing any openings therein, which form boundaries between such lockers and adjoining spaces.

2.11.3 Arrangements for storage on open deck will be specially considered.

2.12 Space heaters

2.12.1 Space heaters, if used, are to be fixed in position and so constructed as to reduce fire risks to a minimum. The design and location of these units are to be such that clothing, curtains or other similar materials cannot be scorched or set on fire by heat from the unit.

2.13 Fixed fire detection and fire-alarm systems

2.13.1 A fixed fire detection and fire-alarm system are to be installed in all Category 'A' machinery spaces and are to comply with the requirements of Pt 16, Ch 1,2.8.

2.13.2 A fixed fire detection and fire-alarm system are to be fitted in all stairways (including lift and dumbwaiter trunks), service spaces, control stations and accommodation spaces (except toilets, bathrooms, void spaces, etc.). The fixed fire detection and fire-alarm system are to be installed in accordance with Ch 4,2.

2.13.3 All yachts at all times when at sea, or in port (except when out of service), are to be so equipped as to ensure that any initial fire-alarm is immediately received by a responsible member of the crew.

2.13.4 A special alarm, operated from the navigating bridge or fire-control station, is to be fitted to summon the crew.

2.14 Fire pumps and fire main system

2.14.1 **Application**. Every yacht is to be provided with a fire pump(s), fire mains, hydrants and hoses as required by this Section.

2.14.2 **Capacity of fire pumps**. The capacity of the fixed main fire pump(s) is not to be less than:

$$Q = (0{,}15\,(L_R\,(B + D))^{1/2} + 2{,}25)^2$$

but need not exceed 25 m^3/hour.

where

B = greatest moulded breadth of yacht, in metres
D = moulded depth to bulkhead deck, in metres
L_R = Rule length of yacht, as defined in Pt 3, Ch 1,6.2.1, in metres
Q = total capacity in m^3/hour.

2.14.3 **Fire pumps**:

(a) A minimum of one fixed power pump and one portable pump or alternative, complying with 2.14.4, are to be provided.
(b) Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil, and that, if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable changeover arrangements are fitted.

(c) In yachts classed for navigation in ice, the fire pump sea inlet valves are to be provided with ice clearing arrangements, *see* Pt 1, Ch 2,3.8.1.
(d) Relief valves are to be provided in conjunction with any fire pump if the pump is capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.
(e) Where centrifugal pumps are provided in order to comply with this Section, a non-return valve is to be fitted in the pipe connecting each pump to the fire main.

2.14.4 **Portable fire pumps**:
(a) Except for electric pumps, which will be specially considered, portable fire pumps are to comply with the following:
  (i) The pump is to be self priming.
  (ii) The suction head in operation is not to exceed 4,5 m.
  (iii) The portable fire pump is to be fitted with a length of discharge hose and nozzle capable of maintaining a pressure sufficient to produce a jet throw of at least 12 m or that required to enable a jet of water to be directed on any part of the engine room or the exterior boundary of the engine room and casing, whichever is the greater.
  (iv) The pump set is to have its own fuel tank of sufficient capacity to operate the pump for three hours.
  (v) Details of the fuel type and storage location are to be submitted. If the fuel type has a flashpoint below 60ºC, further consideration will be given to the fire safety aspects.
  (vi) The pump set is to be stored in a secure, safe and enclosed space, accessible from open deck and clear of the Category 'A' machinery space.
  (vii) The pump set is to be easily moved and operated by two persons and be readily available for immediate use.
  (viii) Arrangements are to be provided to secure the pump at its anticipated operating position(s).
  (ix) The overboard suction hose is to be non-collapsible and of sufficient length to cater for the yacht's motion under all operational conditions. A suitable strainer is to be fitted at the inlet end of the hose.
  (x) Any diesel driven power source for the pump is to be capable of being readily started in its cold condition down to a temperature of 0ºC by hand (manual) cranking.
(b) If it is not possible to comply with the requirements of 2.14.4(a), an additional fixed fire pump will be required, which is to comply with the following:
  (i) The pump, its source of power and sea connection are to be located in accessible positions outside the Category 'A' machinery space, or in a different space to the main fire pump, if the main fire pump is located outside the Category 'A' machinery space.
  (ii) The sea valve is to be capable of being operated from a position near the pump.
  (iii) The room where the fire pump prime mover is located is to be illuminated from the emergency source of electrical power and is to be well ventilated.
  (iv) If the pump is required to supply water for a fixed fire-extinguishing system in the space where the main fire pumps are situated, it is to be capable of simultaneously supplying water to this system and the fire main at the required rates.
  (v) The pump may also be used for other suitable purposes, subject to approval in each case.
  (vi) The pressure and quantity of water delivered by the pump are to be sufficient to produce a jet of water at any nozzle of not less than 12 m.
(c) Means to illuminate the stowage area of the portable pump and its necessary areas of operation are to be provided from the emergency source of electrical power.
(d) If preferred, a pump complying with 2.14.4(b) may be fitted instead of a portable pump complying with 2.14.4(a), *see also* 2.14.8(c).

2.14.5 **Fire main**:
(a) The diameter of the fire main is to be based on the required capacity of the fixed main fire pump(s). The diameter of the water service pipes is to be sufficient to ensure an adequate supply of water for the operation of at least one fire-hose.
(b) The wash deck line may be used as a fire main provided that the requirements of this Section are satisfied.
(c) All exposed water pipes for fire-extinguishing are to be provided with drain valves for use in frosty weather. The valves are to be located where they will not be damaged.

2.14.6 **Pressure in the fire main**. When the fixed main fire pump, or the fire pump described in 2.14.4(b), is delivering the quantity of water required by 2.14.2 through the fire main, fire-hoses and nozzles, the pressure maintained at any hydrant is to be sufficient to produce a jet throw at any nozzle of not less than 12 m.

2.14.7 **Number and position of hydrants**. The number and position of the hydrants are to be such that at least one jet of water is to reach any part normally accessible to any person while the yacht is being navigated. Furthermore, such hydrants are to be positioned near the accesses to the protected spaces. At least one hydrant is to be provided in each Category 'A' machinery space.

2.14.8 **Pipes and hydrants**:
(a) Materials readily rendered ineffective by heat are not to be used for fire mains. For the use of aluminium alloy *see* Pt 15, Ch 1,10.1.4. Where steel pipes are used, they are to be galvanized internally and externally. Cast iron pipes are not acceptable. The pipes and hydrants are to be so placed that the fire-hoses may be easily coupled to them. The arrangement of pipes and hydrants is to be such as to avoid the possibility of freezing. Unless one hose and nozzle is provided for each hydrant in the yacht, there is to be complete interchangeability of hose couplings and nozzles.
(b) A valve is to be fitted at each fire hydrant so that any fire-hose may be removed while the fire pump is at work.

(c) Where an additional fixed fire pump is fitted in accordance with 2.14.4(b) or 2.14.4(d):
   (i) An isolating valve is to be fitted in the fire main so that all the hydrants in the yacht, except those in the Category 'A' machinery space containing the main fire pump, can be supplied with water by the additional fixed fire pump. The isolating valve is to be located in an easily accessible and tenable position outside the Category 'A' machinery space; and
   (ii) the fire main is not to re-enter the machinery space downstream of the isolating valve.

2.14.9 **Fire-hoses**:
(a) Fire-hoses are to be of approved non-perishable material. The hoses are to be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length, in general, is not to exceed 18 m. Each hose is to be provided with a nozzle and the necessary couplings. Fire-hoses, together with any necessary fittings and tools, are to be kept ready for use in conspicuous positions near the water service hydrants or connections.
(b) A minimum of three fire-hoses are to be provided, each complete with couplings and nozzles. These numbers do not include any hoses required in any engine room. If necessary, the number of hoses is to be increased so as to ensure that hoses in sufficient number are available and accessible at all times.

2.14.10 **Nozzles**:
(a) For the purpose of this Chapter, standard nozzle sizes are to be 12 mm, 16 mm or 19 mm, or as near thereto as possible, so as to make full use of the maximum discharge capacity of the fire pump or pumps.
(b) For accommodation and service spaces, the nozzle size need not exceed 12 mm.
(c) The size of nozzles intended for use in conjunction with a portable fire pump need not exceed 12 mm.
(d) All nozzles are to be of an approved dual purpose type (i.e. spray/jet type) incorporating a shut-off.

2.15 Fire-extinguishing arrangements in machinery spaces

2.15.1 **Category 'A' machinery spaces** are to be provided with:
(a) One of the fixed fire-extinguishing systems given in Ch 4,3; and
(b) at least two portable foam extinguishers or equivalent, *see* Ch 4,6.3.2. Where internal combustion machinery is installed, an additional portable extinguisher is to be provided for every 375 kW of power output, but the total number of such additional extinguishers need not exceed five.

2.15.2 **Fire-extinguishing appliances in other machinery spaces**. Where a fire hazard exists in any machinery space for which no specific provisions for fire-extinguishing appliances are prescribed in 2.15.1 or 2.15.3 there is to be provided in or adjacent to that space, a satisfactory number of approved portable fire-extinguishers or other approved means of fire-extinction.

2.15.3 **Machinery spaces, other than Category 'A', in yachts which are constructed mainly or wholly with alternative forms of construction**. In yachts that are constructed mainly or wholly with alternative forms of construction, machinery spaces, other than Category 'A', containing internal combustion machinery, are to comply with the fire-extinguishing requirements for Category 'A' machinery spaces, *see* 2.15.1.

2.16 Automatic sprinkler, fire detection and fire-alarm system

2.16.1 A fixed automatic sprinkler must be fitted in yachts over 350 gross tons, fire detection and fire-alarm system, or equivalent system (e.g. watermist), are to be fitted in all stairways, service spaces, control stations and accommodation spaces, except in general, in spaces which afford no fire risk such as void spaces.

2.16.2 The arrangements are to be in accordance with Ch 4,1, particular attention should be given to Ch 4,1.2.16 and 1.2.17.

2.17 Fixed fire-extinguishing systems not required by this Section

2.17.1 Where a fixed fire-extinguishing system not required by this Chapter is installed, the arrangement is to comply with the relevant requirements of this Chapter.

2.18 Portable fire-extinguishers

2.18.1 All portable fire-extinguishers are to comply with the requirements of Ch 4,6.

2.18.2 The portable fire-extinguishers are to be stowed in readily accessible positions.

2.18.3 One of the portable fire-extinguishers intended for use in any space is to be stowed near the entrance to that space.

2.18.4 At least one portable fire-extinguisher is to be located so that it can easily be reached from the main steering position of the yacht.

2.18.5 Accommodation spaces, service spaces and control stations are to be provided with a sufficient number of portable fire-extinguishers to ensure that at least one extinguisher will be readily available for use in every compartment. In any case, their number is to be not less than three.

2.18.6 Where cooking facilities are provided, a portable fire-extinguisher of a type appropriate to the energy source used is to be located in a position readily accessible for use in the event of a fire.

2.19 Fire blanket

2.19.1 A fire blanket is to be installed in all galleys.

2.20 Protection of spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels

2.20.1 Spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are to be provided with the following:

(a) A fixed fire detection and fire-alarm system complying with the requirements of Pt 16, Ch 1,2.8.
(b) A manually-operated water spray deluge system having a water application rate of 5 litres per square metre of deck area per minute. Where the deck height does not exceed 2,5 m, an application rate of 3,5 litres per square metre of deck area per minute will be accepted. Adequate drainage of the protected spaces is to be provided generally in accordance with the requirements for vehicle or cargo spaces, *see* Pt 3, Ch 4,9.4.4. The drainage piping and connection for the space are to be non-combustible. Other fixed fire-extinguishing systems may be permitted, provided they are not less effective in controlling the type of fire likely to occur.
(c) At least two portable foam extinguishers or equivalent.
(d) An independent mechanical ventilation system, which is entirely separate from other ventilation systems, providing at least six air changes per hour. The ducted air is not to pass through other spaces, except as allowed under 2.8.2, or vent into areas where it could be drawn into accommodation areas or cause undue hazard.
(e) Electrical equipment of a safe type is to be provided, *see* Pt 16, Ch 2,13.
(f) Prominently displayed 'No Smoking' signs.
(g) 'A-30' Class divisions where adjacent to Category 'A' machinery spaces, accommodation or service spaces, or control positions and 'A-0' Class divisions elsewhere.

2.20.2 Such spaces are not to give access to any space other than the fuel store or lockers for use within the space. Lockers storing fuel are to be accessed from an exterior location, unless the locker is within the space containing the vehicles or craft. Exceptionally, where the engine room escape cannot be routed elsewhere, it may exit into the space providing that:

(a) the connecting door is self-closing;
(b) no door hold back devices are fitted;
(c) an audible and visual alarm is fitted on the bridge to signify when the door is open; and
(d) a notice is posted at the door stating that the door is to remain closed and that the area beside the door is an escape route and is to be kept clear.

2.20.3 The requirements of 2.9 are to be complied with, as appropriate.

2.21 Protection of paint lockers and flammable liquid lockers

2.21.1 Paint lockers and flammable liquid lockers with a deck area of 4 m^2 or more are to be provided with a fixed fire-extinguishing system enabling the crew to extinguish a fire without entering the space. One of the following systems is to be provided:

- A carbon dioxide system designed for 40 per cent of the gross volume of the space.
- A dry powder system designed to discharge 0,5 kg powder per cubic metre of gross volume of the space.
- A water spray system designed to give a coverage of 5 litres per square metre of deck area per minute. Water spray systems may be connected to the fire main.

2.21.2 Consideration will be given to the acceptance of other arrangements which provide equivalent protection.

2.21.3 Lockers having a deck area of less than 4 m^2 may be protected by carbon dioxide or dry powder portable extinguishers located near the entrance to the locker.

2.22 Helicopter decks

2.22.1 The requirements of IMO Resolution A.855(20) are to be complied with having due regard to the hazards involved.

2.22.2 If a helicopter hangar is not provided and if two fireman's outfits are supplied as in 2.23.1, then the fireman's outfits required by IMO Resolution A.855(20) need not be provided.

2.23 Fireman's outfit

2.23.1 All yachts of 350 gross tons or more are to carry at least two fireman's outfits complying with the requirements of Ch 4,4.

2.24 Fire-control plans

2.24.1 Fire control plans are to meet the requirements of Ch 4,5.

■ *Section 3*
Fire safety measures for yachts 500 gt or more

3.1 General

3.1.1 Table 3.3.1 is a guide to the major requirements of this Section. The Table is intended as a quick reference to the requirements and is not to be used in isolation when designing the fire safety arrangements.

Table 3.3.1 General fire protection, detection and extinction requirements

Form of construction, *see* 3.2	Steel or equivalent, or alternative forms of construction may be accepted subject to extensive insulation requirements
Passive fire protection, *see* 3.3 to 3.12	*See* Table 3.3.2 and Table 3.3.3
Means of escape, *see* 3.15: • Category 'A' machinery spaces • Accommodation, etc.	} 2
Fixed fire detection system, *see* 3.24	• Fitted in machinery spaces • Fitted in service spaces, control stations and accommodation spaces
Fire pumps, *see* 3.25.1 to 3.25.10	• In general, 2 independent power pumps • For yachts of ≥4000 gross tons: 3 independent power pumps • A fire in any one compartment is not to put all the fire pumps out of action
International shore connection, *see* 3.25.11	At least 1
Fire extinguishing arrangements in Category 'A' machinery spaces, *see* 3.26. *See also* 3.27 for oil fuel units	• A fixed fire extinguishing system • Portable air-foam equipment • 45 litre foam extinguisher • Portable foam extinguishers within 10 m walking distance
Portable fire-extinguishers in accommodation, *see* 3.32	Sufficient to ensure that at least one will be readily available in every compartment, but a minimum of five
Automatic sprinkler system or equivalent, *see* 3.29	Fitted in all yachts
Fireman's outfits, *see* 3.38	At least 2

3.2 Forms of construction – Structure

3.2.1 The hull, superstructure, structural bulkheads, decks and deckhouses may be constructed of steel, other equivalent material, *see* Ch 1,2.1.2 or be of alternative forms of construction, *see* Ch 1,2.1.3.

3.2.2 The structure in way of Category 'A' machinery spaces, galleys containing appliances of significant fire risk and other high risk areas is to be protected such that the material by itself or due to insulation provided can maintain its required strength at the end of 60 minutes exposure to the standard fire test.

3.2.3 Details of the method of construction, supported by calculations and/or fire test data, demonstrating compliance with 3.2.2 are to be submitted.

3.2.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the specified fire exposure.

3.2.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the specified fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the Rules for Materials.

3.2.6 For structures in contact with sea-water, the required insulation should extend to at least 300 mm below the lightest waterline, *see also* 2.6.1.

3.3 Forms of construction – Fire divisions

3.3.1 Fire divisions required by 3.4 are to be constructed in accordance with the remaining paragraphs of 3.3.

3.3.2 Fire divisions using steel equivalent, or alternative forms of construction, may be accepted if it can be demonstrated that the material by itself due to insulation provided, has the fire resistance properties equivalent to 'A' or 'B' Class divisions.

3.3.3 Insulation required by 3.3.2 is to be such that the temperature of the structural core does not rise above the point at which the structure would begin to lose its strength at any time during the applicable exposure to the standard fire test. For 'A' Class divisions, the applicable exposure is 60 minutes, and for 'B' Class divisions, the applicable exposure is 30 minutes.

3.3.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the applicable fire exposure.

3.3.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the applicable fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the Rules for Materials.

3.4 Structural fire protection – Main vertical zones and horizontal zones

3.4.1 The hull, superstructure and deckhouses in way of accommodation and service spaces are to be subdivided into main vertical zones by 'A' Class divisions, *see* Ch 1,2.4.12. These divisions are to have insulation values in accordance with Tables 3.3.2 and 3.3.3.

3.4.2 As far as practicable, the bulkheads forming the boundaries of the main vertical zones above the bulkhead deck are to be in line with watertight subdivision bulkheads situated immediately below the bulkhead deck.

3.4.3 The bulkheads mentioned in 3.4.2 are to extend from deck to deck and to the shell or other boundaries.

Table 3.3.2 Fire integrity of bulkheads separating adjacent spaces

Spaces		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Control stations	(1)	'A-0'(c)	'A-0'	'A-60'	'A-0'	'A-15'	'A-60'	'A-15'	'A-60'	(g)
Corridors	(2)	—	C(d)	'B-0'(d)	'A-0'(a) 'B-0'(d)	'B-0'(d)	'A-60'	'A-0'	'A-15' 'A-0'(f)	(g)
Accommodation spaces	(3)	—	—	C(d)	'A-0'(a) 'B-0'(d)	'B-0'(d)	'A-60'	'A-0'	'A-15' 'A-0'(f)	(g)
Stairways	(4)	—	—	—	'A-0'(a) 'B-0'(d)	'A-0'(a) 'B-0'(d)	'A-60'	'A-0'	'A-15' 'A-0'(f)	(g)
Service spaces (low risk)	(5)	—	—	—	—	C(d)	'A-60'	'A-0'	'A-0'	(g)
Machinery spaces of Category 'A' and spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels	(6)	—	—	—	—	—	'A-60'(b)	'A-0'	'A-60'	(g)
Other machinery spaces	(7)	—	—	—	—	—	—	'A-0'(b)	'A-0'	(g)
Service spaces (high risk)	(8)	—	—	—	—	—	—	—	'A-0'(b)	(g)
Open decks	(9)	—	—	—	—	—	—	—	—	—

NOTES
1. For clarification as to which applies, *see* 3.7.
2. Where spaces are of the same numerical category and superscript (b) appears, a bulkhead or deck of the ratings shown in the Table is only required when the adjacent spaces are for a different purpose, e.g. in category (8), a galley next to a galley does not require a bulkhead, but a galley next to a paint room requires an 'A-0' Class bulkhead.
3. Bulkheads separating the wheelhouse and chartroom from each other may be 'B-0' rating.
4. For the application of 3.4.1 all 'B-0' and 'C' Class bulkheads where appearing in this Table are to be taken as 'A-0' Class.
5. Fire insulation need not be fitted if the machinery space of category (7) has little or no fire risk.
6. Where the spaces are protected by the sprinkler system on both sides of the division, the division may be 'A-0' Class. Where the sprinkler system only protects a space on one side of the division the rating is to be the higher of the two values given.
7. The division is to be of steel, other equivalent material, or alternative forms of construction, but is not required to be of 'A' Class standard. However, where decks, except open decks, are penetrated for the passage of electric cables, pipes and vent ducts, such penetrations are to be made tight to prevent the passage of flame and smoke.
8. For requirements for main vertical zones, *see* 3.4.1.

3.5 Structural fire protection of bulkheads within a main vertical zone

3.5.1 All such divisions may be faced with combustible materials.

3.5.2 When continuous 'B' Class ceilings and/or linings are fitted on both sides of the bulkhead, the portion of the bulkhead behind the continuous ceiling or lining is to be of material which in thickness and composition is acceptable in the construction of 'B' Class divisions but which may meet 'B' Class standards only insofar as is reasonable and practicable.

3.5.3 All bulkheads required to be 'B' Class divisions, except corridor bulkheads prescribed in 3.5.2, are to extend from deck to deck and to the shell or other boundaries unless continuous 'B' Class ceilings or linings fitted on both sides of the bulkhead are at least of the same fire resistance as the bulkhead, in which case the bulkhead may terminate at the continuous ceiling or lining.

3.6 Structural fire protection – Fire integrity of bulkheads and decks

3.6.1 In addition to complying with the specific provisions for fire integrity of bulkheads and decks mentioned elsewhere in this Section the minimum fire integrity of bulkheads and decks are to be as prescribed in Tables 3.3.2 and Table 3.3.3.

3.6.2 For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, such spaces are classified in Table 3.3.2 and Table 3.3.3 according to their fire-risk as shown in space categories ***(1)*** to ***(9)***. The title of each category is intended to be typical (general) rather than restrictive. The number in parentheses preceding each space category refers to the applicable column or row in the Tables.

(1) Control stations:

- Spaces containing emergency sources of power and lighting.
- Wheelhouse and chartroom.
- Spaces containing the ship's radio equipment.
- Fire-extinguishing rooms, fire-control stations and fire recording stations.
- Control room for propulsion machinery when located outside the machinery space.
- Spaces containing centralized fire-alarm equipment.

Table 3.3.3 Fire integrity of decks separating adjacent spaces

		Space above								
Space below		*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
Control stations	*(1)*	'A-0'	'A-0'	'A-0'	'A-0'	'A-0'	'A-60'	'A-0'	'A-0'	(g)
Corridors	*(2)*	'A-0'	(g)	(g)	'A-0'	(g)	'A-60'	'A-0'	'A-0'	(g)
Accommodation spaces	*(3)*	'A-60'	'A-0'	(g)	'A-0'	(g)	'A-60'	'A-0'	'A-0'	(g)
Stairways	*(4)*	'A-0'	'A-0'	'A-0'	(g)	'A-0'	'A-60'	'A-0'	'A-0'	(g)
Service spaces (low risk)	*(5)*	'A-15'	'A-0'	'A-0'	'A-0'	(g)	'A-60'	'A-0'	'A-0'	(g)
Machinery spaces of Category 'A' and spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels	*(6)*	'A-60'	'A-60'	'A-60'	'A-60'	'A-60'	'A-60'	'A-60'(e)	'A-60'	(g)
Other machinery spaces	*(7)*	'A-15'	'A-0'	'A-0'	'A-0'	'A-0'	'A-0'	(g)	'A-0'	(g)
Service spaces (high risk)	*(8)*	'A-60'	'A-30' 'A-0'(f)	'A-30' 'A-0'(f)	'A-30' 'A-0'(f)	'A-0'	'A-60'	'A-0'	'A-0'	(g)
Open decks	*(9)*	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	—

NOTE
See Notes to Table 3.3.2.

(2) Corridors:
- Guest and crew corridors and lobbies.

(3) Accommodation spaces:
- Spaces as defined in Ch 1,2.4.5 excluding corridors.

(4) Stairways:
- Interior stairways, lifts and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto.
- In this connection, a stairway which is enclosed only at one level is to be regarded as part of the space from which it is not separated by a fire door.

(5) Service spaces (low risk):
- Lockers and store-rooms having areas of less than 4 m^2, drying rooms and laundries.

(6) Category 'A' machinery spaces, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels:
- Spaces as defined in Ch 1,2.4.8.

(7) Other machinery spaces:
- Spaces as defined in Ch 1,2.4.9 excluding Category 'A' machinery spaces.

(8) Service spaces (high risk):
- Galleys, pantries containing cooking appliances, paint and lamp rooms, lockers and store-rooms having areas of 4 m^2 or more, spaces for the storage of flammable liquids, bonded stores and workshops other than those forming part of the machinery spaces.

(9) Open decks:
- Open deck spaces and enclosed promenades having no fire-risk. Air spaces (the space outside superstructures and deckhouses).

3.6.3 Continuous 'B' Class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing, wholly or in part, to the required insulation and integrity of a division.

3.7 Structural fire protection – Protection of stairways and lifts in accommodation and service spaces

3.7.1 All stairways are to be of steel construction except where the use of other equivalent material is specially approved, and are to be within enclosures formed of 'A' Class divisions, with positive means of closure at all openings, except that:

(a) A stairway connecting only two decks need not be enclosed, provided that the integrity of the deck is maintained by proper bulkheads or doors at one level to at least 'B-0' Class. When a stairway is closed at one level, the stairway enclosure is to be protected in accordance with Tables 3.3.2 and 3.3.3; and

(b) Stairways may be fitted in the open in a public space, provided that they lie wholly within such public space.

3.7.2 Stairway enclosures are to have a direct access to the corridors and to be of sufficient area to prevent congestion, having in view the number of persons likely to use them in an emergency. Within the perimeter of such stairway enclosures, only toilets and lockers of non-combustible material providing storage for safety equipment are permitted. Only public spaces, corridors, other escape stairways required by 3.15.1(e), pantries containing cooking appliances with an insignificant fire risk, *see* 2.4.2, and external areas are to have direct access to these stairway enclosures. Small corridors or lobbies may be used to separate an enclosed stairway from other spaces.

3.7.3 Lift trunks are to be so fitted as to prevent the passage of smoke and flame from one 'tween deck to another and are to be provided with means of closing so as to permit the control of draught and smoke.

3.8 Structural fire protection – Openings in 'A' Class divisions

3.8.1 The construction of all doors and door frames in 'A' Class divisions, and the means of securing them when closed, is to provide resistance to fire as well as to the passage of smoke and flame, as far as practicable, equivalent to that of the bulkheads in which the doors are situated. Such doors and door frames are to be constructed of steel or other equivalent material. Steel watertight doors need not be insulated.

3.8.2 It is to be possible for each door to be opened and closed from each side of the bulkhead by one person only.

3.8.3 Fire doors in main vertical zone bulkheads and stairway enclosures are to satisfy the following requirements:

(a) The doors shall be self-closing and be capable of closing with an angle of inclination of up to 3,5° opposing closure. The approximate time of closure for hinged fire-doors is to be no more than 40 s and not less than 10 s from the beginning of their movement with the ship in the upright position. The approximate uniform rate of closure for sliding fire doors is to be no more than 0,2 m/s and no less than 0,1 m/s with the ship in the upright position.

(b) Remote-controlled sliding or power-operated doors are to be equipped with an alarm that will sound not less than 5 s but no more than 10 s before the door begins to move and will continue to sound until the door is completely closed. Doors designed to re-open upon contacting an object in its path are to re-open sufficiently to allow a clear passage of at least 0,75 m but not more than 1 m.

(c) All doors are to be capable of remote and automatic release from the continuously manned central control station, either simultaneously or in groups and also individually from a position at both sides of the door. Indication is to be provided at the fire control panel in the continuously manned central control station whether each of the remotely-controlled doors are closed. The release mechanism is to be so designed that the door will automatically close in the event of disruption of the control system or central power supply. Release switches shall have an on-off function to prevent automatic resetting of the system. Hold-back devices not subject to central control station release are not permitted.

(d) Local power accumulators for power-operated doors are to be located in the immediate vicinity of the doors. They are to have the capacity to enable the doors to be fully opened and closed at least 10 times using local controls.

(e) Double-leaf doors dependent on a latch to maintain their fire integrity are to be arranged so that the latch is automatically activated by the action of the closing doors.

(f) Doors which are power-operated and automatically closed, giving direct access to special category spaces need not be equipped with the alarms and remote release mechanisms required by (b) and (c).

(g) The components of the local control system are to be accessible for maintenance and adjusting.

3.8.4 Where 'A' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for girders, beams or other structural members, arrangements are to be made to ensure that the fire resistance is not impaired.

3.9 Structural fire protection – Openings in steel outer boundaries

3.9.1 The requirements for steel or other equivalent material on the outer boundaries of a yacht do not apply to glass partitions, windows and sidescuttles. The requirements of 3.11.2 for such boundaries to have 'A' class integrity are to be adhered to.

3.10 Structural fire protection – Openings in 'B' Class divisions

3.10.1 Doors and door frames in 'B' Class divisions and means of securing them are to provide a method of closure which has resistance to fire as far as practicable equivalent to the divisions they serve, except that ventilation openings may be permitted in the lower portion of such doors. Where such openings are in or under a door the total net area of any such opening or openings is not to exceed 0,05 m^2. When such an opening is cut in a door it is to be fitted with a grill made of non-combustible material. Bridging ducts are not allowed in fire divisions.

3.10.2 Cabin doors in 'B' class divisions are to be self-closing. Hold-backs are not permitted.

3.10.3 Where 'B' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for the fitting of ventilation terminals, lighting fixtures and similar devices, arrangements are to be made to ensure that the fire resistance is not impaired.

3.11 Structural fire protection – Windows and side scuttles

3.11.1 Notwithstanding the requirements of Table 3.3.2 and Table 3.3.3, all windows and side scuttles in bulkheads separating accommodation and service spaces and control stations from weather are to be constructed with frames of steel or other suitable material. The glass is to be retained by a metal glazing bead or angle. Alternative forms of construction and retention will be considered.

3.11.2 Glass is not to be installed as an interior main vertical zone or stairway enclosure bulkhead.

3.11.3 For yachts having a freeboard length of 85 m and over, windows and side scuttles situated in the yacht's side shell below the life raft and escape slide embarkation areas and below lifeboat embarkation areas are to have fire integrity of at least equal to 'A-0' Class.

3.12 Structural fire protection – Details of construction

3.12.1 In accommodation and services spaces, control stations, corridors and stairways, air spaces enclosed behind ceilings, panelling or linings are to be suitably divided by close-fitting draught stops not more than 7 m apart. In the vertical direction, such spaces, including those behind linings of stairways, trunks, etc., are to be closed at each deck.

3.12.2 The draught stops are to be non-combustible and are to form a continuation above the ceiling of the bulkhead below or the other side of the panelling or lining to the bulkhead, as far as possible.

3.12.3 Where the structure or 'A' Class divisions are required to be insulated, it is to be ensured that the heat from a fire is not transmitted through the intersections and terminal points of the divisions or penetrations to uninsulated boundaries. Where the insulation installed does not achieve this, arrangements are to be made to prevent this heat transmission by insulating the horizontal and vertical boundaries or penetrations for a distance of 450 mm.

3.13 Structural fire protection – Materials

3.13.1 Except in cargo spaces, mail rooms, baggage rooms, or refrigerated compartments, of service spaces, all insulation (e.g. fire and comfort) is to be of non-combustible materials. Partial bulkheads or decks used to subdivide a space for utility or artistic treatment are to have a non-combustible core.

3.13.2 The use of combustible materials is to be kept to a minimum.

3.13.3 Pipes penetrating 'A' or 'B' Class divisions are to be of approved materials having regard to the temperature such divisions are required to withstand.

3.13.4 Pipes conveying oil or combustible liquids through accommodation and service spaces are to be of approved materials having regard to the fire risk.

3.13.5 Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.

3.13.6 Primary deck coverings within accommodation spaces, service spaces and control stations are to be of a type which will not readily ignite, or give rise to toxic or explosive hazards at elevated temperatures. Reference is also to be made to the IMO FTP Code, Annex 1, Parts 2 and 6.

3.13.7 Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings for cold service systems need not be non-combustible, but they shall be kept to the minimum quantity practicable and their exposed surfaces shall have low flame spread characteristics.

3.13.8 All waste receptacles are to be constructed of non-combustible materials with no openings in the sides or bottom.

3.13.9 Furniture in the stairway enclosures is to be limited to seating. If required, it is to be fixed, limited to four seats on each deck in each stairway enclosure and is not to obstruct the escape route. Additional seating may be permitted in the main reception area within a stairway enclosure provided it is fixed and does not obstruct the escape route. Furniture is not permitted in corridors forming escape routes in cabin areas. Lockers for the storage of safety equipment may be permitted.

3.14 Structural fire protection – Surface of insulation

3.14.1 In spaces where penetration of oil products is possible, the surface of insulation is to be impervious to oil or oil vapours. Insulation boundaries are to be arranged to avoid immersion in oil spillages so far as is practicable.

3.15 Structural fire protection – Means of escape

3.15.1 Stairways and ladders are to be arranged to provide ready means of escape to the survival craft embarkation deck from all guest and crew spaces and from spaces in which the crew is normally employed, other than machinery spaces. In particular, the following provisions are to be complied with:

(a) Below the bulkhead deck, two means of escape, at least one of which is to be independent of watertight doors, are to be provided for each watertight compartment or similarly restricted space or group of spaces. One of these means of escape may be dispensed with, due regard being paid to the nature and the location of spaces concerned, and to the number of persons who normally might be accommodated or employed there.

(b) Above the bulkhead deck, there are to be at least two practical means of escape from each main vertical zone or similarly restricted space or group of spaces, at least one of which is to give access to a stairway forming a vertical escape.

(c) If a radio-telegraph station has no direct access to the open deck, two means of escape from or access to such station are to be provided, one of which may be a port-hole or window of sufficient size or other satisfactory means to provide an emergency escape.

(d) A corridor, lobby, or part of a corridor from which there is only one route of escape is not to exceed 7 m. Where accommodation arrangements are such that access to compartments is through another compartment, as is often the case with an Owner's suite, a second means of escape is to be provided. The second escape route is to be as remote as possible from the main escape route. The second means of escape may be through portholes or hatches of adequate size, leading to the open deck.

(e) At least one of the means of escape required by (a) or (b) is to be by means of a readily accessible enclosed stairway, which will provide continuous fire shelter from the level of its origin to the appropriate survival craft embarkation decks, or the uppermost weather deck if the embarkation deck does not extend to the main vertical zone being considered. In the latter case, direct access to the embarkation deck by external open stairways and passageways is to be provided and is to have emergency lighting and slip-free surfaces underfoot. Boundaries facing external open stairways and passageways forming part of an escape route and boundaries in such a position that their failure during a fire would impede escape to the embarkation deck, are to have fire integrity and insulation values in accordance with Tables 3.3.2 and 3.3.3. The widths, number and continuity of escape routes are to be as follows:
  - (i) Stairways are to be not less than 900 mm clear width between handrails. Stairways are to be fitted with handrails on each side. The minimum clear width of stairways is to be increased by 10 mm for every person provided for in excess of 90 persons. The maximum clear width between handrails where stairways are wider than 900 mm is to be 1800 mm. The total number of persons to be evacuated by such stairways is to be two-thirds of the crew and total number of passengers in the areas served by such stairways.
  - (ii) Stairways with a clear width in excess of 900 mm are to be aligned in a fore-and-aft direction.
  - (iii) Doorways, corridors and intermediate landings included in the means of escape are to have widths sized in the same manner as the stairways.
  - (iv) Stairways are not to exceed 3,5 m vertical rise without the provision of a landing and are not to have angle of inclination greater than 45° to the horizontal.
  - (v) Landings at each deck level are to be not less than 2 m^2 in area and are to be increased by 1 m^2 for every 10 persons provided for in excess of 20 persons but need not exceed 16 m^2, except for those landings serving public spaces having direct access onto the stairway enclosure.

(f) Protection of access from the stairway enclosures to the survival craft embarkation areas are to comply with the requirements of Tables 3.3.2 and 3.3.3.

(g) Where public spaces span three or more open decks, contain combustibles such as furniture and give access to other enclosed spaces, each level within the space is to have two means of escape, one of which is to give direct access to an enclosed vertical means of escape meeting the requirements of (e).

(h) Where a dispensation has been granted under the provisions of (a), a safe means of escape is to be provided. Stairways are to be provided with handrails on both sides and are to have a clear width between handrails of not less than 800 mm.

3.15.2 Two means of escape are to be provided from each machinery space. In particular, the following provisions are to be complied with:

(a) Where the space is below the bulkhead deck the two means of escape are to consist of either:
  - (i) Two sets of steel ladders and walkways as widely separated as possible, leading to doors in the upper part of the space similarly separated and from which access is provided to the appropriate survival craft embarkation decks. One of these ladders is to provide continuous fire shelter from the lower part of the space to a safe position outside the space. This shelter is to be of steel or equivalent material, insulated where necessary, and provided with a self closing door of steel or equivalent material at the lower end. If access is provided at other levels each level is to be provided with a door of steel or equivalent material; or
  - (ii) one steel ladder leading to a door in the upper part of the space from which access is provided to the embarkation deck and additionally, in the lower part of the space and in a position well separated from the ladder referred to, a steel or equivalent material door capable of being operated from each side and which provides access to a safe escape route from the lower part of the space to the embarkation deck.

(b) Where the space is above the bulkhead deck, the two means of escape are to be as widely separated as possible and the doors leading from such means of escape are to be in positions from which access is provided to the appropriate survival craft embarkation decks. Where such means of escape require the use of ladders these are to be of steel.

3.15.3 One of the means of escape from any such space required by 3.15.2 may be dispensed with, so long as either a door or a steel ladder and walkways provides a safe escape route to the embarkation deck, due regard being paid to the nature and location of the space and whether persons are normally employed in that space.

3.15.4 Two means of escape are to be provided from a machinery control room located inside a machinery space, at least one of which is to provide continuous fire shelter to a safe position outside the machinery space.

3.15.5 Adequate deck area is to be provided at muster stations and embarkation areas having due regard to the expected number of persons.

3.16 Ventilation systems

3.16.1 Ventilation ducts are to be of non-combustible material. Short lengths of ducts not exceeding 2 m in length and with a cross-section not exceeding 0,02 m^2 need not be non-combustible, subject to these ducts being:

(a) of a material that has low flame spread characteristics;
(b) used at the end of the ventilation device; and
(c) situated not less than 600 mm, measured along the duct, from an opening in an 'A' or 'B' Class division including continuous 'B' Class ceilings.

3.16.2 Where the ventilation ducts with a free cross-sectional area exceeding 0,02 m^2 pass through Class 'A' bulkheads or decks, the openings are to be lined with a steel sheet sleeve unless the ducts passing through the bulkheads or decks are of steel in the vicinity of passage through the deck or bulkhead and the ducts and sleeves are to comply in this part with the following:

(a) Steel ducts, or sleeves lining such ducts, are to have a thickness of at least 3 mm and a length of at least 900 mm. When passing through bulkheads, this length is to be divided preferably into 450 mm on each side of the bulkhead. These ducts, or sleeves lining such ducts, are to be provided with fire insulation. The insulation is to have at least the same fire integrity as the bulkhead or deck through which the duct passes.

(b) Steel ducts with a free cross-sectional area exceeding 0,075 m^2 are to be fitted with fire dampers in addition to the requirements of (a). The fire damper is to operate automatically but is also to be capable of being closed manually from both sides of the bulkhead or deck. The damper is to be provided with an indicator which shows whether the damper is open or closed. Fire dampers are not required, however, where ducts pass through spaces surrounded by 'A' Class divisions, without serving those spaces, provided those ducts have the same fire integrity as the divisions which they pierce.

(c) Compliance with 3.8.4.

3.16.3 Ventilation ducts with a free cross-sectional area exceeding 0,02 m^2 passing through 'B' Class bulkheads are to be lined with steel sheet, or other equivalent material, sleeves of 900 mm in length divided preferably into 450 mm on each side of the bulkheads unless the duct is of steel for this length, *see also* 3.10.3.

3.16.4 Ducts provided for the ventilation of Category 'A' machinery spaces, galleys, spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels, are not to pass through accommodation spaces, service spaces or control stations unless the ducts are:

(a) either:
   (i) constructed of steel having a thickness of at least 3 mm and 5 mm for ducts the widths or diameters of up to and including 300 mm and 760 mm and over respectively and, in the case of such ducts, the widths or diameters of between 300 mm and 760 mm having a thickness to be obtained by interpolation;
   (ii) suitably supported and stiffened;
   (iii) fitted with automatic fire dampers close to the boundaries penetrated; and
   (iv) insulated to 'A-60' Class standard from the machinery spaces, galleys, spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels, to a point at least 5 m beyond each fire damper;

(b) or:
   (i) constructed of steel in accordance with (a)(i) and (ii); and
   (ii) insulated to 'A-60' Class standard throughout the accommodation spaces, service spaces or control stations;

except that penetrations of main zone divisions are also to comply with 3.16.8.

3.16.5 Ducts provided for ventilation to accommodation spaces, service spaces or control stations are not to pass through such spaces, unless, where they pass through Category 'A' machinery space, galleys, spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels, the ducts:

(a) either:
   (i) are constructed of steel in accordance with 3.16.4(a)(i) and (ii);
   (ii) are fitted with automatic fire dampers close to the boundaries penetrated; and
   (iii) have the integrity of boundaries of the machinery space, galley, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, maintained at the penetrations;

(b) or:
   (i) are constructed of steel in accordance with 3.16.4(a)(i) and (ii); and
   (ii) are insulated to 'A-60' Class standard within the machinery space, galley or spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels;

except that penetration of main zone divisions is also to comply with 3.16.8.

3.16.6 Such measures as are practicable are to be taken in respect of control stations outside machinery spaces in order to ensure that ventilation, visibility and freedom from smoke are maintained, so that in the event of fire the machinery and equipment contained therein may be supervised and continue to function effectively. Alternative and separate means of air supply are to be provided; air inlets of the two sources of supply are to be so disposed that the risk of both inlets drawing in smoke simultaneously is minimised. Such requirements need not apply to control stations situated on, and opening on to, an open deck, or where local closing arrangements would be equally effective.

3.16.7 Where they pass through accommodation spaces or spaces containing combustible materials, the exhaust ducts from galley ranges are to comply with 3.16.4. Such exhaust ducts are to be fitted with:

(a) a grease trap readily removable for cleaning;
(b) a fire damper located in the lower end of the duct;
(c) arrangements, operable from within the galley, for shutting off the exhaust fans; and
(d) fixed means for extinguishing a fire within the duct.

3.16.8 Where it is necessary that a ventilation duct passes through a main vertical zone division, a fail-safe automatic closing fire damper is to be fitted adjacent to the division. The damper is also to be capable of being manually closed from each side of the division. The operating position is to be readily accessible and be marked in red light-reflecting colour. The duct between the division and the damper is to be of steel or other equivalent material and, if necessary, insulated to comply with 3.8.4. The damper is to be fitted on at least one side of the division with a visible indicator showing whether the damper is in the open position.

3.16.9 Where public spaces span three or more open decks and contain combustibles such as furniture and other enclosed spaces, the space is to be equipped with a smoke extraction system. The smoke extraction system is to be activated by the smoke detection system required by Ch 4,2 and is to be capable of manual control. The fans are to be capable of exhausting the entire volume within the space in not more than 10 min.

3.16.10 The main inlets and outlets of all ventilation systems are to be capable of being closed from outside the spaces being ventilated.

3.16.11 Power ventilation of accommodation spaces, service spaces, control stations and machinery spaces is to be capable of being stopped from an easily accessible position outside the space being served. This position should not be readily cut off in the event of a fire in the spaces served. The means provided for stopping the power ventilation of the machinery spaces is to be entirely separate from the means provided for stopping ventilation of other spaces, *see also* Pt 16, Ch 2,16.6.

3.16.12 Reference is also made to 2.8.4 to 2.8.7, 2.8.9 and 3.10.1.

3.16.13 Ducts provided for exhaust ventilation from laundries are to be fitted with suitably located cleaning and inspection openings.

3.16.14 Fire dampers required by 3.16.2, 3.16.4, 3.16.5 and 3.16.8, including relevant means of operation are to be fire tested. Reference is also to be made to IMO FTP Code, Annex 1, Part 3.

3.17 Oil fuel arrangements

3.17.1 In a yacht in which oil fuel is used, the arrangements for the storage, distribution and utilization of the oil fuel are to be such as to ensure the safety of the yacht and persons on board. For details, *see* Pt 15, Ch 3.

3.17.2 As far as practicable, oil fuel tanks are to be part of the yacht's structure and are to be located outside Category ‘A’ machinery spaces.

3.17.3 Where oil fuel tanks, other than double bottom tanks, are necessarily located adjacent to or within Category ‘A’ machinery spaces, at least one of their vertical sides is to be contiguous to the machinery space boundaries, and is preferably to have a common boundary with the double bottom tanks, and the area of the tank boundary common with the machinery spaces is to be kept to a minimum. Where the vertical boundary of a tank directly exposed to a machinery space meets the yacht's side plating at an acute angle, a small horizontal surface at the base of the tank, necessary to accommodate practical constructional considerations may be permitted. If the arrangement of the machinery is such that a tank with a large horizontal surface at the base is necessary then a cofferdam with suitable ventilation arrangements, to protect the base of the tank from the effect of a machinery space fire, will be specially considered. *See also* Pt 15, Ch 3. Oil fuel tanks situated within the boundaries of Category ‘A’ machinery spaces are not to contain oil fuel having a flashpoint of less than 60°C. The use of free-standing oil fuel tanks is prohibited.

3.18 Lubricating oil arrangements

3.18.1 The arrangements for the storage, distribution and utilization of oil used in pressure lubrication systems are to be such as to ensure the safety of the yacht and persons on board, *see also* Pt 15, Ch 3.

3.19 Arrangements for other flammable oils

3.19.1 The arrangements for the storage, distribution and utilization of other flammable oils employed under pressure in power transmission systems, control and activating systems and heating systems are to be such as to ensure the safety of the ship and persons on board, *see also* Pt 15, Ch 3.

3.20 Prohibition of carriage of flammable oils in forepeak tanks

3.20.1 Oil fuel, lubricating oil and other flammable oils are not to be carried in forepeak tanks.

3.21 Special arrangements in Category ‘A’ machinery spaces

3.21.1 Openings are to be provided with closing appliances constructed so as to maintain the fire integrity of the machinery space boundaries.

3.21.2 Doors other than power operated watertight doors, are to be so arranged that positive closure is assured in case of fire in the space, by power-operated closing arrangements or by the provision of self-closing doors capable of closing against an inclination of 3,5° opposing closure and having a fail-safe hook-back facility, provided with a remotely operated release device.

3.21.3 Windows are not to be fitted in machinery space boundaries. This does not preclude the use of glass in control rooms within the machinery spaces.

3.21.4 Means of control are to be provided for:
(a) closure of openings which normally allow exhaust ventilation, and closure of ventilator dampers;
(b) permitting the release of smoke;
(c) closing power-operated doors or actuating release mechanism on doors other than power-operated watertight doors;
(d) stopping ventilating fans; and
(e) stopping forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps and other similar fuel pumps.

3.21.5 The controls required in 3.21.4 are to be located outside the space concerned, where they will not be cut off in the event of fire in the space they serve. Such controls and the controls for any required fire-extinguishing system are to be situated at one control position or grouped in as few positions as possible. Such positions are to have a safe access from the open deck, *see also* Pt 15, Ch 3,4.5.1 and 4.9.2.

3.21.6 When access to any Category 'A' machinery space is provided at a low level from an adjacent space there is to be provided near the watertight door, a light steel fire-screen door operable from each side.

3.22 Arrangements for gaseous fuel for domestic purposes

3.22.1 Where gaseous fuel is used for domestic purposes, the arrangements for the storage, distribution and utilization of the fuel is to be such that, having regard to the hazards of fire and explosion which the use of such fuel may entail, the safety of the yacht and the persons on board is preserved. The installation is to be in accordance with recognized National or International Standards.

3.22.2 Storage lockers for gas cylinders are to be provided with:

(a) effective ventilation;

(b) an outward-opening door accessible directly to the open deck; and

(c) gas-tight boundaries, including doors and other means of closing any openings therein, which form boundaries between such lockers and adjoining enclosed spaces.

3.23 Space heaters

3.23.1 Space heaters, if used, are to be fixed in position and so constructed as to reduce fire risks to a minimum. The design and location of these units are to be such that clothing, curtains or other similar materials cannot be scorched or set on fire by heat from the unit.

3.24 Fixed fire detection and fire-alarm systems

3.24.1 A fixed fire detection and fire-alarm system is to be installed in any machinery space and is to comply with the requirements of Pt 16, Ch 1,2.8.

3.24.2 A fixed fire detection and fire-alarm system is to be fitted in all stairways (including lift and dumbwaiter trunks), service spaces, control stations and accommodation spaces (except toilets, bathrooms, void spaces, etc.). The fixed fire detection and fire-alarm system is to be installed in accordance with Ch 4,2.

3.24.3 All yachts at all times when at sea, or in port (except when out of service), are to be so equipped as to ensure that any initial fire-alarm is immediately received by a responsible member of the crew.

3.24.4 A special alarm, operated from the navigating bridge or fire-control station, is to be fitted to summon the crew.

3.24.5 For yachts having a freeboard length of 85 m or more, a public address system is to be available throughout the accommodation spaces, service, and control stations and open decks. The arrangements are to comply with Pt 16, Ch 2,17.3.

3.25 Fire pumps and fire main system

3.25.1 **Application**. Every yacht is to be provided with fire pumps in accordance with this Section. Fire mains, hydrants and hoses are also to be provided as required by this Section.

3.25.2 **Capacity of fire pumps**:

(a) The fire pumps required are to be capable of delivering for fire-fighting purposes a quantity of water, at the pressure specified in 3.25.5 of not less than two-thirds of the quantity required to be dealt with by the bilge pumps when employed for bilge pumping. For number and capacity of bilge pumps, *see* Pt 15, Ch 2.

(b) As an alternative to (a) the capacity of fire pumps may be determined by hydrostatic calculations based on the requirement of 3.25.5(a).

(c) Where more pumps than the minimum number of required pumps are installed the capacity of such additional pumps will be specially considered.

3.25.3 **Fire pumps**:

(a) In yachts of 4000 tons gross or more, at least three independently driven fire pumps are to be provided and, in yachts of less than 4000 tons gross, at least two such fire pumps.

(b) Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil, and that, if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable changeover arrangements are fitted.

(c) In yachts classed for navigation in ice, the fire pump sea inlet valves are to be provided with clearing arrangements, *see* Pt 1, Ch 2,3.8.1.

(d) The arrangements of sea connections, fire pumps and their sources of power are to be such as to ensure that in the event of a fire in any one compartment, all the fire pumps will not be put out of action.

(e) The arrangements for the ready availability of water supply are to be as follows:

   (i) In yachts of 1000 gross tons or more, or any yacht of an alternative form of construction, the arrangements are to be such that at least one effective jet of water is immediately available from any hydrant in an interior location and so as to ensure the continuation of the output of water by the automatic starting of a required fire pump.

   (ii) Yachts not provided with arrangements complying with (i), but to which a UMS notation is to be assigned, are to have remote starting of a required fire pump from the navigating bridge and fire-control station, if any.

(f) Relief valves are to be provided in conjunction with any fire pump if the pump is capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.

(g) Where centrifugal pumps are provided in order to comply with this sub-Section, a non-return valve is to be fitted in the pipe connecting the pump to the fire main.

3.25.4 **Fire main**:

(a) The diameter of the fire main is to be based on the required capacity of two fire pumps, and the diameter of the water service pipes are to be sufficient to ensure an adequate supply of water for the simultaneous operation of at least two fire-hoses. In general, the diameter of the fire main is to be not less than:

$d = (L_{pp}/1,2) + 25$ mm

but need not exceed 180 mm in yachts, and is in no case to be less than 50 mm

where

d = internal diameter of the fire main, in mm

L_{pp} = length of yacht measured between perpendiculars, in metres, as defined in Pt 3, Ch 1,6.2.2.

(b) The wash deck line may be used as a fire main provided that the requirements of this sub-Section are satisfied.

(c) All exposed water pipes for fire-extinguishing are to be provided with drain valves for use in frosty weather. The valves are to be located where they will not be damaged.

3.25.5 **Pressure in the fire main**:

(a) The fire pumps, associated piping and fire main are to be so designed that the following minimum pressures will be maintained at all hydrants under conditions where two fire pumps required by 3.25.3 are simultaneously delivering water to the fire main of the size required by 3.25.4 through adjacent nozzles of sizes required by 3.25.9:

4000 tons gross and over	4 bar (0,4 N/mm^2)
Less than 4000 tons gross	3 bar (0,3 N/mm^2)

(b) The maximum pressure at any hydrant shall not exceed that at which the effective control of a fire-hose can be demonstrated.

3.25.6 **Number and position of hydrants**:

(a) The number and position of the hydrants are to be such that at least two jets of water not emanating from the same hydrant, one of which is to be from a single length of hose, may reach any part of the yacht normally accessible to the guests and crew while the yacht is being navigated. In yachts of 1000 tons gross or more, at least two hydrants are to be provided in the machinery spaces; in smaller yachts one hydrant will be accepted.

(b) In the accommodation, service and machinery spaces, the number and position of hydrants are to be such that the requirements of (a) may be complied with when all watertight doors and all doors in main vertical zone bulkheads are closed.

(c) Where access is provided to a machinery space of Category 'A' at a low level, two hydrants are to be provided external to, but near the entrance, to that machinery space.

3.25.7 **Pipes and hydrants**:

(a) Materials readily rendered ineffective by heat are not to be used for fire mains. Where steel pipes are used, they are to be galvanized internally and externally. Cast iron pipes are not acceptable. The pipes and hydrants are to be so placed that the fire-hoses may be easily coupled to them. The arrangement of pipes and hydrants is to be such as to avoid the possibility of freezing. Unless one hose and nozzle is provided for each hydrant in the yacht, there is to be complete interchangeability of hose couplings and nozzles.

(b) A valve is to be fitted at each fire hydrant so that any fire-hose may be removed while the fire pump is at work.

(c) Isolating valve(s) to isolate the section of the fire main within the Category 'A' machinery space containing the main fire pump(s) from the rest of the fire main are to be fitted in an easily accessible and tenable position outside the Category 'A' machinery space. The fire main is to be so arranged that when the isolating valve(s) is shut, all the hydrants on the yacht, except those in the Category 'A' machinery space referred to above, can be supplied with water by a fire pump not located in this Category 'A' machinery space through pipes which do not enter this space.

3.25.8 **Fire-hoses**:

(a) Fire-hoses are to be of approved non-perishable material. The hoses are to be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length, in general, is not to exceed 18 m. Each hose is to be provided with a nozzle and the necessary couplings. Fire-hoses, together with any necessary fittings and tools, are to be kept ready for use in conspicuous positions near the water service hydrants or connections.

(b) There is to be at least one fire-hose for each of the hydrants required by 3.25.6.

3.25.9 **Nozzles**:

(a) For the purpose of this Chapter, standard nozzle sizes are to be 12 mm, 16 mm or 19 mm, or as near thereto as possible, so as to make full use of the maximum discharge capacity of the fire pumps.

(b) For accommodation and service spaces, the nozzle size need not exceed 12 mm.

(c) For machinery spaces and exterior locations, the nozzle size is to be such as to obtain the maximum discharge possible from two jets at the pressure indicated in 3.25.5 from the smallest pump, however a nozzle size greater than 19 mm need not be used.

(d) All nozzles are to be of an approved dual purpose type (i.e. spray/jet type) incorporating a shut-off.

3.25.10 **Location and arrangement of water pumps, etc., for other fire-extinguishing systems**. Pumps required for the provision of water for other fire-extinguishing systems required by this Chapter are to have their sources of power and their controls installed outside the space or spaces protected by such systems and are to be so arranged that a fire in the space or spaces protected will not put any such system out of action.

3.25.11 **International shore connection**. At least one international shore connection is to be provided.

3.26 Fire-extinguishing arrangements in spaces containing internal combustion machinery

3.26.1 Category 'A' machinery spaces containing internal combustion machinery are to be provided with:

(a) one of the fire-extinguishing systems described in Ch 4,3;
(b) at least one set of portable air-foam equipment complying with 3.29;
(c) in each such space approved foam type fire-extinguishers, each of at least 45 litres capacity or equivalent, sufficient in number to enable foam or its equivalent to be directed on to any part of the fuel and lubricating oil pressure systems, gearing and other fire hazards; and
(d) a sufficient number of portable foam extinguishers or equivalent are to be located so that no point in the space is more than 10 m walking distance from an extinguisher and that there are at least two such extinguishers in each such space.

3.26.2 Machinery spaces in yachts which are constructed mainly or wholly with alternative forms of construction, containing internal combustion machinery, are to comply with the requirements of 3.26.1.

3.27 Fire-extinguishing arrangements in spaces containing oil fuel units

3.27.1 Category 'A' machinery spaces containing oil fuel units are to be provided with one of the fixed fire-extinguishing systems described in Ch 4,3.

3.27.2 There are to be at least two portable foam extinguishers or equivalent in each space in which a part of the oil fuel unit is situated.

3.28 Limitations on the use of oil as a fuel

3.28.1 For the limitations of the use of oil as a fuel, *see* Pt 15, Ch 3.

3.29 Automatic sprinkler, fire detection and fire-alarm system

3.29.1 A fixed automatic sprinkler, fire detection and fire-alarm system, or equivalent system (e.g. watermist), is to be fitted in all stairways, service spaces, control stations and accommodation spaces except spaces which afford no fire risk such as void spaces.

3.29.2 The arrangements are to be in accordance with Ch 4,1.

3.30 Fixed fire-extinguishing systems not required by this Section

3.30.1 Where a fixed fire-extinguishing system not required by this Section is installed, the arrangement is to comply with the relevant requirements of this Chapter.

3.31 Portable foam applicator

3.31.1 A portable foam applicator unit is to consist of an air foam nozzle of an inductor type capable of being connected to the fire main by a fire-hose, together with a portable tank containing at least 20 litres of foam-making liquid and one spare tank. The nozzle is to be capable of producing effective foam, suitable for extinguishing an oil fire, at the rate of at least 1,5 m^3/min.

3.32 Portable fire-extinguishers

3.32.1 All fire-extinguishers are to comply with the requirements of Ch 4,6.

3.32.2 The extinguishers are to be stowed in readily accessible positions.

3.32.3 One of the portable fire-extinguishers, or the portable fire-extinguisher, dedicated for use in any space is to be stowed near the entrance to that space.

3.32.4 At least one portable fire-extinguisher is to be located so that it can easily be reached from the main steering position of the yacht.

3.32.5 Accommodation spaces, service spaces and control stations are to be provided with a sufficient number of portable fire-extinguishers to ensure that at least one extinguisher will be readily available for use in every compartment. In any case, their number is to be not less than five.

3.32.6 Where cooking facilities are provided, a portable fire-extinguisher of a type appropriate to the energy source used is to be located in a position readily accessible for use in the event of a fire.

3.33 Fire blanket

3.33.1 A fire blanket is to be installed in all galleys.

3.34 Protection of spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels

3.34.1 Spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are to be provided with the following:

(a) A fixed fire detection and fire-alarm system complying with the requirements of Pt 16, Ch 1,2.8.

(b) A manually-operated water spray deluge system having a water application rate of 5 litres per square metre of deck area per minute. Where the deck height does not exceed 2,5 m, an application rate of 3,5 litres per square metre of deck area per minute will be accepted. Adequate drainage of the protected spaces is to be provided generally in accordance with the requirements for vehicle or cargo space, *see* Pt 3, Ch 4,9.4.4. The drainage piping and connections for the space are to be non-combustible. Other fixed fire-extinguishing systems may be permitted, provided they are not less effective in controlling the type of fire likely to occur.
(c) At least two portable foam extinguishers, or equivalent;
(d) An independent mechanical ventilation system , which is entirely separate from other ventilation systems, providing at least six air changes per hour. The ducted air is not to pass through other spaces, except as allowed under 3.16.4, or vent into areas where it could be drawn into accommodation areas or cause undue hazard.
(e) Electrical equipment of a safe type is to be provided, *see* Pt 16, Ch 2,13.
(f) Prominently displayed 'No Smoking' signs; and
(g) Structural fire protection as required by Table 3.3.2 and Table 3.3.3.

3.34.2 Such spaces are not to give access to any space other than the fuel store or lockers for use within the space. Lockers storing fuel are to be accessed from an exterior location, unless the locker is within the space containing the vehicles or craft. Exceptionally, where the engine room escape cannot be routed elsewhere, it may exit into the space providing that:
(a) the connecting door is self-closing;
(b) no door hold-back devices are fitted;
(c) an audible and visual alarm is fitted on the bridge to signify when the door is open; and
(d) a notice is posted at the door stating that the door is to remain closed and that the area beside the door is an escape route and is to be kept clear.

3.34.3 The requirements of 3.17 are to be complied with, as appropriate.

3.35 Protection of paint lockers and flammable liquid lockers

3.35.1 Paint lockers and flammable liquid lockers of deck area 4 m^2 or more are to be provided with a fixed fire-extinguishing system enabling the crew to extinguish a fire without entering the space. One of the following systems is to be provided:

- A carbon dioxide system designed for 40 per cent of the gross volume of the space.
- A dry powder system designed to discharge 0,5 kg powder per cubic metre of gross volume of the space.
- A water spray system designed to give a coverage of 5 litres per square metre of deck area per minute. Water spray systems may be connected to the fire main.

3.35.2 Consideration will be given to the acceptance of other arrangements which provide equivalent protection.

3.35.3 Lockers having a deck area less than 4 m^2 may be protected by carbon dioxide or dry powder portable extinguishers located near the entrance to the locker.

3.36 Arrangements where deep fat cooking equipment is installed

3.36.1 Where deep-fat cooking equipment is installed, all installations are to be fitted with:
(a) an automatic or manual fixed extinguishing system type approved in accordance with ISO 15371, *Ships and marine technology-Fire extinguishing systems for protection of galley deep-fat cooking equipment-Fire tests*, or an acceptable alternative National or International Standard, for protection of the deep-fat cooking equipment;
(b) a primary and back up thermostat with an alarm to alert the operator in the event of failure of either thermostat;
(c) arrangements for automatically shutting off the deep-fat cooking equipment electrical power upon activation of the fire-extinguishing system;
(d) an alarm for indicating operation of the fire-extinguishing system in the galley where the equipment is installed; and
(e) controls for manual operation of the fire-extinguishing system which are clearly labelled for ready use by the crew.

Control and electrical engineering arrangements are to be in accordance with the requirements of Pt 16, Ch 1 and Ch 2, as applicable.

3.36.2 For fryers of up to 15 litres cooking oil capacity, the provision of a suitably sized extinguisher of a suitable type located for specific use on the cooking equipment together with manual isolation of the electrical power supply may be considered an acceptable alternative to 3.36.1 provided the arrangements are to the satisfaction of the National Administration.

3.37 Helicopter decks

3.37.1 The requirements of IMO Resolution A.855(20) are to be complied with having due regard to the hazards involved.

3.37.2 If a helicopter hangar is not provided and if two fireman's outfits are supplied as per 3.38.1, then the fireman's outfits required by IMO Resolution A.855(20) need not be provided.

3.38 Fireman's outfit

3.38.1 Each yacht is to carry at least two fireman's outfits complying with Ch 4,4. Additional fireman's outfits are to be provided as applicable to ensure that at least two fireman's outfits are stored in each main vertical zone.

3.38.2 The fireman's outfits are to be so stored as to be easily accessible and ready for use. Where more than two fireman's outfits are required, they are to be located in widely separated positions. At least two fireman's outfits are to be available at any one position.

3.38.3 Additional sets of personal equipment and breathing apparatus, may be required, having due regard to the size of the yacht.

3.39 Fire-control plans

3.39.1 Fire-control plans are to meet the requirements of Ch 4,5.

■ *Section 1* Automatic sprinkler, fire detection and fire-alarm systems

1.1 General

1.1.1 Any required automatic water sprinkler and fire-alarm and fire detection system is to be designed for immediate use at any time. Where such a system is fitted, it is to be of the wet pipe type . Any part of the system which may be subjected to freezing temperatures in service are to be suitably protected against freezing. It is to be kept charged at the necessary pressure and have provision for a continuous supply of water.

1.1.2 As an alternative to the system specified in 1.1.1, any one of the following systems may be considered:

(a) **Dry pipe system**. A sprinkler system employing automatic sprinklers attached to a piping system containing air or nitrogen under pressure, the release of which (as from the opening of a sprinkler) permits the water pressure to open a valve known as a dry pipe valve. The water then flows into the piping system and out of the opened sprinklers.

(b) **Pre-action system**. A sprinkler system employing automatic sprinklers attached to a piping system containing air that may or may not be under pressure, with a supplemental detection system installed in the same area as the sprinklers. Actuation of the detection system opens a valve that permits water to flow into the sprinkler piping system and to be discharged from any sprinklers that may be open.

(c) **Deluge system**. A sprinkler system employing open sprinklers attached to a piping system connected to a water supply through a valve that is opened by the operation of a detection system installed in the same areas as the sprinklers. When this valve opens water flows into the piping system and discharges from all sprinklers attached thereto.

1.2 Wet pipe type

1.2.1 Any required automatic sprinkler, fire detection and fire-alarm system is to comply with the requirements of Pt 16, Ch 2,16.2.

1.2.2 Sprinklers are to be grouped into separate sections, each of which is to contain not more than 200 sprinklers. Any section of sprinklers is not to serve more than two decks nor be situated in more than one main vertical zone, except where it is satisfactorily shown that the protection of the yacht against fire will not thereby be reduced.

1.2.3 Each section of sprinklers is to be capable of being isolated by one stop valve only. The stop valve in each section is to be readily accessible and its location is to be clearly and permanently indicated. Means are to be provided to prevent the operation of the stop valves by any unauthorized person.

1.2.4 A gauge indicating the pressure in the system is to be provided at each section stop valve and at a central station.

1.2.5 The sprinklers are to be resistant to corrosion by marine atmosphere. In accommodation and service spaces the sprinklers are to come into operation within the temperature ranges from 68°C to 79°C, except that in locations such as drying rooms, where high ambient temperatures might be expected, the operating temperature may be increased by not more than 30°C above the maximum deck head temperature.

1.2.6 A list or plan is to be displayed at each indicating unit showing the spaces covered and the location of the zone in respect of each section. Suitable instructions for testing and maintenance are to be available.

1.2.7 Sprinklers are to be placed in an overhead position and spaced in a suitable pattern to maintain an average application rate of not less than 5 litres per square metre per minute over the nominal area covered by the sprinklers. The use of sprinklers providing other amounts of water suitably distributed, will be considered provided they are shown to be not less effective.

1.2.8 A pressure tank having a volume equal to at least twice that of the charge of water specified in 1.2.9 is to be provided.

1.2.9 The tank is to contain a standing charge of fresh water, equivalent to the amount of water which would be discharged in one minute by the pump referred to in 1.2.12, and the arrangements are to provide for maintaining such air pressure in the tank to ensure that where the standing charge of fresh water in the tank has been used the pressure will be not less than the working pressure of the sprinkler, plus the pressure exerted by a head of water measured from the bottom of the tank to the highest sprinkler in the system. Suitable means of replenishing the air under pressure and of replenishing the fresh water charge in the tank are to be provided. A glass gauge suitably protected is to be provided to indicate the correct level of the water in the tank.

1.2.10 Means are to be provided to prevent the passage of sea water into the tank.

1.2.11 An independent power pump is to be provided solely for the purpose of automatically continuing the discharge of water from the sprinklers. The pump is to be brought into action automatically by the pressure drop in the system before the standing fresh water charge in the pressure tank is completely exhausted.

1.2.12 The pump and the piping system are to be capable of maintaining the necessary pressure at the level of the highest sprinkler to ensure a continuous output of water sufficient for the simultaneous coverage of a minimum area of the maximum width of the craft squared or 280 m^2 whichever is the less, at the application rate specified in 1.2.7.

1.2.13 The pump is to have fitted on the delivery side a test valve with a short open-ended discharge pipe. The effective area through the valve and pipe is to be adequate to permit the release of the required pump output while maintaining the pressure in the system specified in 1.2.9.

1.2.14 The sea inlet to the pump is to be, wherever possible, in the space containing the pump and is to be so arranged that when the vessel is afloat it will not be necessary to shut off the supply of sea water to the pump for any purpose other than the inspection or repair of the pump.

1.2.15 The sprinkler pump and tank are to be situated in a position reasonably remote from any machinery space of Category 'A' and not in any space required to be protected by the sprinkler system.

1.2.16 Where the arrangement precludes locating the pump and tank in accordance with 1.2.15, for yachts of not greater than 50 m Rule length, the sprinkler pump and tank required by Ch 3,2.16 may be situated within Category 'A' machinery spaces, but not within the spaces that are protected by the system.

1.2.17 For yachts of not greater than 50 m Rule length and all service craft, the sources of electrical power supply for the sea-water pump may be fed from the main source of electrical power.

1.2.18 There are to be not less than two sources of power supply for the sea water pump and automatic alarm and detection system. Where one of the sources of power for the pump is an internal combustion engine it is to be so situated that a fire in any protected space will not affect the air supply to the machinery, in addition to complying with 1.2.15. When the sources of power for the pump are electrical, *see* Pt 16, Ch 2,2 and Pt 16, Ch 2,3.

1.2.19 The sprinkler system is to have a connection from the vessel's fire main by way of a lockable screw-down non-return valve at the connection which will prevent a backflow from the sprinkler system to the fire main.

1.2.20 A test valve is to be provided for testing the automatic alarm for each section of sprinklers by a discharge of water equivalent to the operation of one sprinkler. The test valve for each section is to be situated near the stop valve for that section.

1.2.21 Means are to be provided for testing the automatic operation of the pump, on reduction of pressure in the system.

1.2.22 Each section of sprinklers is to include means for giving a visual and audible alarm signal automatically at one or more indicating units whenever any sprinkler comes into operation. Such alarm systems are to be arranged to indicate if any fault occurs in the system. Such units are to indicate in which section, served by the system, fire has occurred and are to be centralized on the navigation bridge. In addition, visible and audible alarms from the unit are to be located in a position other than on the navigation bridge, so as to ensure that the indication of fire is immediately received by the crew. Switches are to be provided at one of these indicating positions, which will enable the alarm and the indicators for each section of sprinklers to be tested.

1.2.23 Spare sprinkler heads are to be provided as specified in Table 4.1.1. The spare sprinkler heads are to be stowed in boxes or holders provided for that purpose, together with a tool suitable for removing and installing sprinkler heads. The boxes or holders are to be situated near the control valve for the section, and are to be clearly and permanently marked to indicate their contents.

Table 4.1.1 Spares requirements

Number of sprinkler heads provided	Number of spare sprinkler heads required
300	One spare sprinkler head is to be provided for each 50 sprinkler heads fitted, with a minimum of one spare being provided for each type fitted
301 to 1000	12
>1000	24

1.3 Arrangements which will be accepted as an alternative to 1.2

1.3.1 The alternative system is to be tested, type approved and installed in accordance with IMO Resolution A.800(19). The following exceptions to Section 3 of the Annex may be applied:

(a) Where the arrangement precludes locating the pump and tank in accordance with 1.2.15, for yachts not greater than 50 m Rule length, the sprinkler pump and tank required by Ch 3,2.16 may be situated within Category 'A' machinery spaces, but not within the spaces that are protected.

(b) Pumps and alternative supply components are to be sized so as to be capable of maintaining the required flow to the hydraulically most demanding area of not less than the maximum width of the craft squared or 280 m^2 whichever is the less.

1.3.2 Spare nozzles are to be provided as specified in Table 4.1.2. The spare nozzles are to be stowed in boxes or holders provided for that purpose, together with a tool suitable for removing and installing nozzles. The boxes or holders are to be situated near the control valve for the section, and are to be clearly and permanently marked to indicate their contents.

Table 4.1.2 Spares requirements

Number of nozzles provided	Number of spare nozzles required
300	One spare nozzle is to be provided for each 50 nozzles fitted, with a minimum of one spare being provided for each type fitted
301 to 1000	12
>1000	24

■ *Section 2*

Fixed fire detection and fire-alarm systems

2.1 General requirements

2.1.1 Any required fixed fire detection and fire-alarm system with manually operated call points is to be capable of immediate operation at all times.

2.1.2 Fire detection systems are to comply with the requirements of Pt 16, Ch 2,16.1 in addition to the requirements of this Section.

2.1.3 Detectors are to be operated by heat, smoke or other products of combustion, flame, or any combination of these factors. Detectors operated by other factors indicative of incipient fires may be considered provided that they are no less sensitive than such detectors. Flame detectors are only to be used in addition to smoke or heat detectors.

2.1.4 Suitable instructions for testing and maintenance are to be provided.

2.1.5 For each type of detector installed, one spare detector head is to be provided for every 10 heads or part thereof. They are to be stowed in a suitable container at the control station.

2.1.6 The function of the detection system is to be periodically tested by means of equipment producing hot air at the appropriate temperature, or smoke or aerosol particles having the appropriate range of density or particle size, or other phenomena associated with incipient fires to which the detector is designed to respond. All detectors are to be of a type such that they can be tested for correct operation and restored to normal surveillance without the renewal of any component.

2.2 Installation requirements

2.2.1 Manually operated call points are to be installed throughout the accommodation spaces, service spaces and control stations. One manually operated call point is to be located at each exit. Manually operated call points are to be readily accessible in the corridors of each deck such that no part of the corridor is more than 20 m from a manually operated call point.

2.2.2 Smoke detectors are to be installed in all stairways, corridors and escape routes within accommodation spaces.

2.2.3 Where a fixed fire detection and fire-alarm system is required for the protection of spaces other than those specified in 2.2.2, at least one detector complying with 2.1.3, is to be installed in each such space.

2.2.4 Detectors are to be located for optimum performance. Positions near beams and ventilation ducts or other positions where patterns of air flow could adversely affect performance and positions where impact or physical damage is likely are to be avoided. In general, detectors which are located overhead are to be a minimum distance of 0,5 m away from bulkheads.

2.2.5 The maximum spacing of detectors is to be in accordance with Table 4.2.1. Other spacings based upon test data which demonstrate the characteristics of the detectors may be required or permitted.

Table 4.2.1 Maximum spacing of detectors

Maximum		Maximum	
Maximum floor		Distance apart between centres, in metres	Distance away from bulkheads, in metres
Type of detector	Area per detector, m^2		
Heat	37	9	4,5
Smoke	74	11	5,5

2.2.6 Electrical wiring which forms part of the system is to be so arranged as to avoid galleys, machinery spaces of Category 'A', and other enclosed spaces of high fire-risk except where it is necessary to provide for fire detection or fire-alarm in such spaces or to connect to the appropriate power supply. *See also* Pt 16, Ch 2.

2.3 Design requirements

2.3.1 Smoke detectors required by 2.2.2 are to be certified to operate before the smoke density exceeds 12,5 per cent obscuration per metre, but not until the smoke density exceeds two per cent obscuration per metre. Smoke detectors to be installed in other spaces are to operate within satisfactory sensitivity limits having regard to the avoidance of detector insensitivity or oversensitivity.

2.3.2 Heat detectors are to be certified to operate before the temperature exceeds 78°C but not until the temperature exceeds 54°C, when the temperature is raised to those limits at a rate less than 1°C per minute. At higher rates of temperature rise, the heat detector is to operate within satisfactory temperature limits having regard to the avoidance of detector insensitivity or oversensitivity.

2.3.3 The permissible temperature of operation of heat detectors may be increased to 30°C above the maximum deckhead temperature in drying rooms and similar spaces of a normal high ambient temperature.

2.4 Requirements for machinery spaces

2.4.1 The arrangements of the fixed fire detection and fire-alarm system in machinery spaces are to comply with the requirements of Pt 16, Ch 1,2.8.

■ *Section 3* Fixed fire-extinguishing systems in machinery spaces

3.1 Gas fire-extinguishing systems

3.1.1 The use of a fire-extinguishing medium which, either by itself or under expected conditions of use, gives off toxic gases in such quantities as to endanger persons is not permitted.

3.1.2 New installations that use fire-extinguishing media, which have ozone-depleting properties under the Montreal Protocol, are not permitted.

3.1.3 The necessary pipes for conveying a fire-extinguishing medium into protected spaces are to be provided with control valves which are to be so placed that they will be easily accessible and not readily cut off from use by an outbreak of fire. The control valves are to be so marked as to indicate clearly the spaces to which the pipes are led. Suitable provision is to be made to prevent inadvertent admission of the medium to any space. Where pipes pass through accommodation spaces they are to be seamless and the number of pipe joints is to be kept to a minimum and made by welding.

3.1.4 The piping for the distribution of fire-extinguishing medium is to be of adequate size and so arranged, and discharge nozzles so positioned that a uniform distribution of medium is obtained. All pipes are to be arranged to be self draining and where led into refrigerated spaces, the arrangement will be specially considered. A means whereby the individual pipes to all protected spaces can be tested using compressed air is to be provided. Distribution pipes are to extend at least 50 mm beyond the last nozzle.

3.1.5 Steel pipes fitted in spaces where corrosion is likely to occur are to be galvanized, at least internally.

3.1.6 Distribution pipes for carbon dioxide are not to be smaller than 20 mm bore.

3.1.7 Means are to be provided to close all openings which may admit air into, or allow gas to escape from, a protected space.

3.1.8 The volume of starting air receivers, converted to free air volume, is to be added to the gross volume of the machinery space when calculating the necessary quantity of extinguishing medium. Alternatively a discharge pipe from the safety valves may be fitted and led directly to the open air.

3.1.9 Means are to be provided for automatically giving audible and visual warning of the release of fire-extinguishing medium into any space in which personnel normally work or to which they have access. The alarm is to operate for a suitable period before the medium is released.

3.1.10 Where pneumatically operated alarms are fitted which require periodic testing, carbon dioxide is not to be used as an operating medium. Air operated alarms may be used provided that the air supply is clean and dry.

3.1.11 Where electrically operated alarms are used, the arrangements are to be such that the electric operating mechanism is located outside hazardous spaces.

3.1.12 The means of control of any fixed gas fire-extinguishing system is to be readily accessible and simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in a protected space. At each location there is to be clear instructions relating to the operation of the system having regard to the safety of personnel. Two separate controls are to be provided for releasing carbon dioxide into a protected space and each is to ensure the activation of the alarm. One control is to be used to discharge the gas from its storage cylinder(s). A second control is to be used for opening the valve of the piping which conveys the gas into the protected space. The two controls are to be located inside a release box clearly identified for the particular space. If the box containing the controls is to be locked, a key to the box is to be in a break-glass type enclosure conspicuously located adjacent to the box. There is to be a dedicated release box for each protected space, in which personnel normally work or to which they have access (*see also* 3.1.9). The space served is to be identified at the release box.

3.1.13 Automatic release of fire-extinguishing medium is not permitted.

3.1.14 Where the quantity of extinguishing medium is required to protect more than one space, the quantity of medium available need not be more than the largest quantity required for any one space so protected.

3.1.15 Means are to be provided for the crew to safely check the quantity of medium in the containers.

3.1.16 Containers for the storage of fire-extinguishing media and associated pressure components are to be designed and tested to Codes of Practice recognized by Lloyd's Register (hereinafter referred to as 'LR') having regard to their locations and the maximum ambient temperatures expected in service.

3.1.17 The fire-extinguishing medium is to be stored outside a protected space, in a room which is situated in a safe and readily accessible position and effectively ventilated. Any entrance to such a storage room is to preferably be from the open deck and in any case be independent of the protected space. Access doors are to open outwards, and bulkheads and decks including doors and other means of closing any opening therein, which form the boundaries between such rooms and adjoining enclosed spaces are to be gastight. Such storage rooms are to be treated as control stations.

3.1.18 In systems where containers discharge into a common manifold, non-return valves are to be provided at the connections of the container discharge pipes to the manifold to allow any container to be disconnected without preventing the use of other containers in the system and to prevent the discharge of extinguishing medium into the container storage room in the event of the system being operated. Manifolds are to be tested by hydraulic pressure to 1,5 times the design pressure. The design pressure is the maximum gauge pressure to which the system may be subjected and is not to be less than the gauge pressure corresponding to the maximum ambient temperature expected in service. The design pressure need not be greater than the maximum setting of the manifold pressure relief valve. After the hydraulic test, manifolds are to be carefully cleaned and dried before the non-return valves are finally fitted.

3.1.19 For craft on unrestricted service, spare parts for the system are to be stored on board. As a minimum these are to consist of:

- 1 actuator;
- 1 flexible hose (cylinder to manifold); and
- the cylinder bursting discs and sealing washers for all cylinders.

3.2 Carbon dioxide systems

3.2.1 Carbon dioxide systems are to comply with 3.1 in addition to the remaining requirements of this sub-Section.

3.2.2 For the purpose of this paragraph the volume of free carbon dioxide is to be calculated at 0,56 m^3/kg.

3.2.3 For machinery spaces:

(a) The quantity of carbon dioxide carried is to be sufficient to give a minimum volume of free gas equal to the larger of:
   - 40 per cent of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40 per cent or less of the horizontal area of the space concerned taken midway between the tank top and the lowest part of the casing; or
   - 35 per cent of the gross volume of the largest machinery space protected, including the casing.

(b) The above mentioned percentages may be reduced to 35 per cent and 30 per cent respectively for craft less than 2000 gross tons.

(c) The fixed piping system is to be such that 85 per cent of the gas can be discharged into the space within two minutes.

(d) The distribution arrangements are to be such that approximately 15 per cent of the required quantity of carbon dioxide is led to the bilge areas.

3.2.4 Two separate controls are to be provided for releasing carbon dioxide into a protected space and each is to ensure the activation of the alarm. One control is to be used to discharge the gas from its storage cylinder(s). A second control is to be used for opening the valve of the piping which conveys the gas into the protected space. The two controls are to be located inside a release box clearly identified for the particular space. If the box containing the controls is to be locked, a key to the box is to be in a break-glass type enclosure conspicuously located adjacent to the box. There is to be a dedicated release box for each protected space in which personnel normally work or to which they have access, *see also* 3.1.8. The space served is to be identified at the release box.

3.3 High-expansion foam systems

3.3.1 Any required fixed high-expansion foam system in machinery spaces is to be capable of rapidly discharging through fixed discharge outlets a quantity of foam sufficient to fill the greatest space to be protected at a rate of at least 1 m in depth per minute. The quantity of foam-forming liquid available is to be sufficient to produce a volume of foam equal to five times the volume of the largest space to be protected.

3.3.2 The expansion ratio of the foam is not to exceed 1000 to 1.

3.3.3 Alternative arrangements and discharge rates will be permitted provided that equivalent protection is achieved.

3.3.4 Supply ducts for delivering foam, air intakes to the foam generator and the number of foam producing units are to be such as will provide effective foam production and distribution.

3.3.5 The arrangement of the foam generator delivery ducting is to be such that a fire in the protected space will not affect the foam-generating equipment.

3.3.6 The foam generator, its sources of power supply, foam-forming liquid and means of controlling the system are to be readily accessible and simple to operate and are to be grouped in as few locations as possible at positions not likely to be cut off by fire in the protected space. Such spaces are to be treated as control stations.

3.3.7 Foam concentrates are to be of an approved type.

3.4 Pressure water-spraying systems

3.4.1 Any required fixed pressure water-spraying fire-extinguishing system in machinery spaces is to be provided with spraying nozzles of an approved type.

3.4.2 The number and arrangement of the nozzles is to be such as to ensure an effective average distribution of water of at least five litres per square metre per minute in the spaces to be protected. Where increased application rates are considered necessary, these will be specially considered. Nozzles are to be fitted above bilges, tank tops and other areas over which oil fuel is liable to spread and also above other specific fire hazards in the machinery spaces.

3.4.3 The system may be divided into sections, the distribution valves of which are to be operated from easily accessible positions outside the spaces to be protected and which will not be readily cut off by fire in the protected space.

3.4.4 The system is to be kept charged at the necessary pressure, and the pump supplying the water for the system is to be put automatically into action by a pressure drop in the system.

3.4.5 The pump is to be capable of simultaneously supplying, at the necessary pressure, all sections of the system in any one compartment to be protected. The pump and its controls are to be installed outside the space or spaces to be protected. It is not to be possible for a fire in the space or spaces protected by the water-spraying system to put the system out of action.

3.4.6 The pump may be driven by independent internal combustion type machinery but if it is dependent upon power being supplied from the emergency generator, that generator is to be arranged to start automatically in case of main power failure so that power for the pump required by 3.4.5 is immediately available. When the pump is driven by independent internal combustion machinery it is to be so situated that a fire in the protected space will not affect the air supply to the machinery.

3.4.7 Precautions are to be taken to prevent the nozzles from becoming clogged by impurities in the water or corrosion of the piping, nozzles, valves and pump.

3.5 Arrangements which will be accepted as an alternative to 3.4

3.5.1 The system is to be tested, type approved and installed in accordance with MSC/Circ. 668 as amended by IMO MSC/Circ. 728.

3.6 Other systems

3.6.1 Other fixed fire-extinguishing systems will be specially considered.

3.6.2 The use of steam as a fire-extinguishing medium in fixed fire-extinguishing systems is not permitted.

■ *Section 4* Fireman's outfits

4.1 Components

4.1.1 A fireman's outfit is to consist of:

(a) Personal equipment comprising:
- (i) Protective clothing of material to protect the skin from the heat radiating from the fire and from burns and scalding by steam. The outer surface is to be water-resistant.
- (ii) Boots and gloves of rubber or other electrically non-conducting material.
- (iii) A rigid helmet providing effective protection against impact.
- (iv) An electric safety lamp (hand lantern) of an approved type with a minimum burning period of three hours.
- (v) An axe with an insulated handle.

(b) A self contained breathing apparatus of an approved type. The volume of air contained in the cylinders of which is to be at least 1200 litres or other self contained breathing apparatus which is to be capable of functioning for a period of at least 30 minutes. Spare bottles are to be provided which are to be maintained fully charged except where facilities for re-charging the bottles are available on board. At least two spare charges for each breathing apparatus are to be provided, and all air cylinders for breathing apparatus are to be interchangeable.

4.1.2 For each breathing apparatus a fireproof life-line of sufficient length and strength is to be provided capable of being attached by means of a snaphook to the harness of the apparatus or to a separate belt in order to prevent the breathing apparatus becoming detached when the life-line is operated.

■ *Section 5* Fire-control plans

5.1 Description of plans

5.1.1 General arrangement plans are to be permanently exhibited for the guidance of the ship's officers,using graphical symbols in accordance with IMO Resolution A.654(16), which show clearly for each deck the control stations, the various fire sections enclosed by steel or 'A' and 'B' Class divisions, together with particulars of:
- the fire detection and fire-alarm system;
- any sprinkler installation;
- the fire-extinguishing appliances;
- the means of access to different compartments, decks, etc.;
- the position of the fireman's outfits;
- the ventilating system, including particulars of the fan control positions, the position of dampers and identification numbers of the ventilating fans serving each section; and

- the location and arrangement of the emergency stop(s) for pumps, and for remote closing the valves on the pipes from tanks, for oil fuel, lubricating oil and other flammable oils.

5.1.2 Alternatively, the details required by 5.1.1 may be set out in a booklet, a copy of which is to be supplied to each officer, and one copy is at all times to be available on board in an accessible position.

5.1.3 The plans and booklets are to be kept up to date, any alterations being recorded thereon as soon as practicable. Description in such plans and booklets is to be in the official language of the flag state. If the language is neither English nor French, a translation into one of those languages is to be included. In addition, instructions concerning the maintenance and operation of all the equipment and installations on board for the fighting and containment of fire are to be kept under one cover, readily available in an accessible position.

5.1.4 A duplicate set of fire-control plans or a booklet containing such plans is to be permanently stored in a prominently marked weathertight enclosure outside the deckhouse for the assistance of shoreside fire-fighting personnel.

■ *Section 6* Fire-extinguishers (portable and non-portable)

6.1 Approved types

6.1.1 All fire-extinguishers are to be of approved types and designs.

6.2 Extinguishing medium

6.2.1 The extinguishing media employed are to be suitable for extinguishing fires in the compartments in which they are intended to be used.

6.2.2 The extinguishers required for use in the machinery spaces using oil as fuel are to be of a type suitable for extinguishing oil fires.

6.2.3 Fire-extinguishers containing an extinguishing medium which, either by itself or under expected conditions of use, gives off toxic gases in such quantities as to endanger persons, are not permitted.

6.3 Capacity

6.3.1 The capacity of required portable fluid extinguishers is to be not more than 13,5 litres but not less than nine litres. Other extinguishers are to be at least as portable as the 13,5 litre fluid extinguishers and are to have a fire-extinguishing capability at least equivalent to a 9,0 litre fluid extinguisher.

6.3.2 The following capacities may be taken as equivalents:
- 9 litre fluid extinguisher;
- 4,5 kg dry powder;
- 5 kg carbon dioxide.

6.4 Spare charges

6.4.1 A spare charge is to be provided for each required portable fire-extinguisher which can be readily re-charged on board. If this cannot be done, duplicate extinguishers are to be provided.

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